Computer Graphics and Computer Animation: A Retrospective Overview

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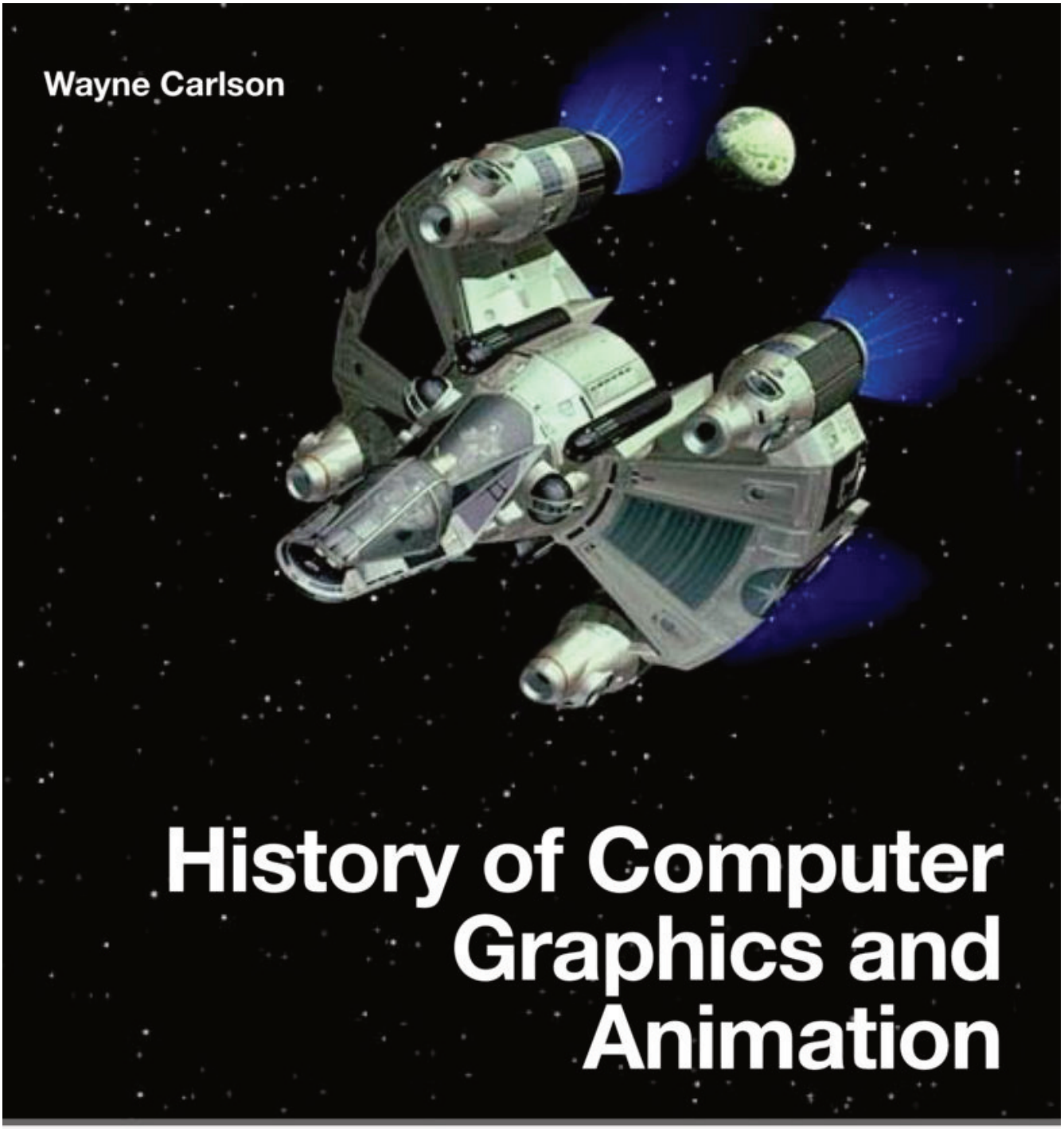
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Opening Animation

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/HistoryCG-1-1.m4v

ACM SIGGRAPH premiered the feature length documentary, “The Story of Computer Graphics,” on Sunday, 8 August 1999, at the Shrine Auditorium in Los Angeles to kick off the SIGGRAPH 99 conference. Mastered in HD, the film includes historical graphics and visual elements, and features behind-the-scene interviews with over 50 pioneers in the industry. Carl Machover and John Hart were Executive Producers, Steve Silas, Producer, Frank Foster, Director, Joan Collins, Co-Producer, and was written by Judson Rosebush.

Note: Front cover photo produced by Digital Productions (see Chapter 6).

Chapter 1: The history of early computing technology

The history of early computing technology

Early contributions to computation influenced the development of graphics technology. This chapter addresses some of the more important of these contributions.



Radiosity Factory, Cornell University – 1988

The study of the history of CGI (computer generated imagery) is an important part of our overall educational experience, not necessarily to build on the historical precedent, but to gain an understanding of the evolution of our discipline and to gain a respect for the key developments that have brought us to where we are. The discipline is so recent in its early developments and so rapidly changing that we are in fact living it, and it evolves as we speak. Yet we have been so busy in advancing the discipline that we have often neglected to accurately record this history. So we will decide to agree upon certain past events in order to begin to develop a definitive record of what has transpired in this evolutionary process.

We must learn from the past, as we develop a theory and methodology which is tuned to the capabilities and qualities inherent in software, hardware, animation techniques, etc. that are part of our broad, contemporary, and creative computer graphics environment. It is in this context that this e-book has been developed.

Herbert Freeman, in an introduction to his 1980 IEEE compilation of computer graphics papers, presents a succinct overview of the first two decades of the development of the CGI discipline.[1] Like many other disciplines, computer graphics and animation has a rich (albeit relatively short) history that involves the following four eras, which are very much linked and related:

1. pioneers
2. innovators
3. adapters
4. followers

Early pioneers include artists (such as Chuck Csuri and John Whitney) and researchers (such as Ivan Sutherland and Ken Knowlton). These visionaries saw the possibilities of the computer as a resource for making and interacting with pictures, and pushed the limits of an evolving technology to take it where computer scientists never imagined it could go. Their work motivated the work of the others as they tried to realize the potential of this new vision. In this book, we will survey work from Sutherland, Csuri and Whitney, National Research Council of Canada (Burtnyk, Wein and Foldes), Michael Noll, Lillian Schwartz and Ken Knowlton, and others.

Many of the so-called innovators were housed in universities and research labs, and were working toward solving fundamental problems of making “pictures” of data using the computer. We will survey work from many of these facilities, including Bell Labs, Ohio State, University of Utah, New York Institute of Technology, Evans & Sutherland and several aerospace and automotive companies, MIT, and others. Individual work of Nelson Max, Jim Blinn, Loren Carpenter, Turner Whitted, and others will also be reviewed.

The early adapters included pioneering CGI production facilities, artists, researchers, and research labs and industries with an interest in converting much of this early work into a viable (and marketable) tool for realizing their disparate goals. Notable companies include Robert Abel and Associates, Digital Effects, MAGI, Information International Inc., and others. Artists include more from Whitney Sr., Yoichiro Kawaguchi, David Em, and others.

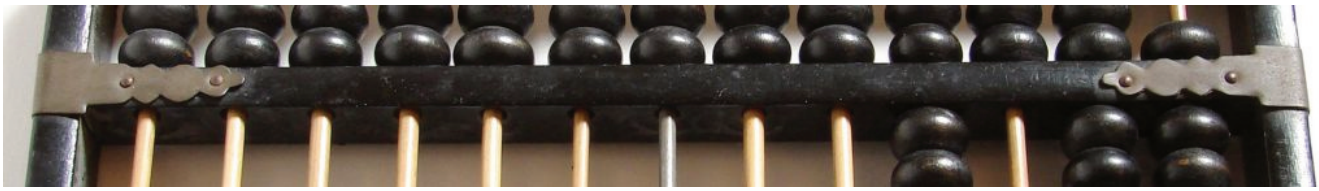
The late seventies and early eighties saw the second wave of adapters, which were primarily special effects production companies, equipment and software developers, universities, motion picture companies, etc. We will

1. Tutorial and Selected Readings in Interactive Computer Graphics, IEEE computer Society tutorials, Herbert Freeman, IEEE Computer Society, 1980

survey work from Pacific Data Images, Cranston/Csuri Productions, Digital Productions, Omnibus Computer Graphics, Bo Gehring, and others.

As the technology advanced and the acceptance of this new approach to image making increased, the industry likewise evolved, and many of the current contributors, or followers (this descriptor is not intended to be demeaning or derogatory) came into being. These include effects production companies such as Pixar, Disney, Metrolight, Rhythm and Hues, ILM, Xaos, and others. We will also look at work from universities such as Cal Tech, Cornell, Ohio State, UNC, University of Illinois-Chicago, etc., and companies and research labs such as Apple, Sun, Xerox, SGI, Microsoft, Alias, Softimage, and others. We will look at the impact on related areas, such as HCI, design, multimedia, virtual reality, scientific visualization, etc.

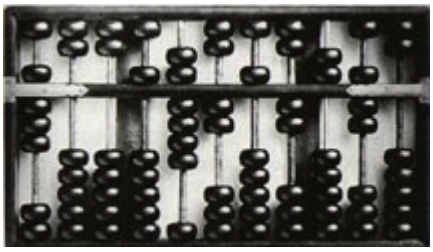
1.1 Early analog computational devices



In order to adequately discuss the beginnings of computer graphics, we need to step back further in history and investigate a number of contributions that influenced the way we do things. Some of the innovations still are used in one form or another today.

http://www.computerhistory.org/timeline/

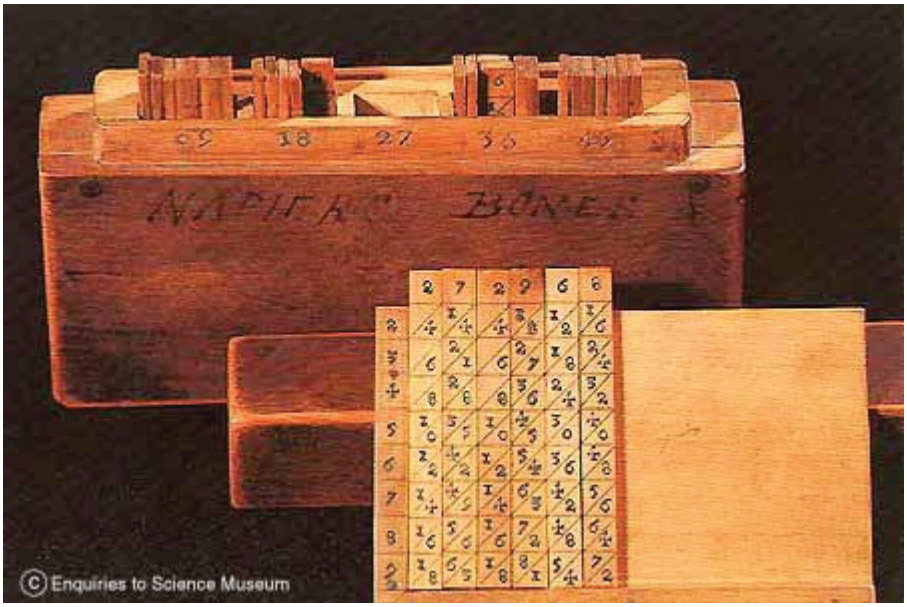
The Abacus



Computing or calculating instruments date back to the abacus, used by early man to represent a positional counting notation that was used in counting tables, called abaci. They were really not calculators per se, but provided a technique to keep track of sums and carries in addition. Although the abacus existed as far back as 5 A.D. the abacus as we know it was attributed to the Chinese in 1200 AD.

Napier's Bones

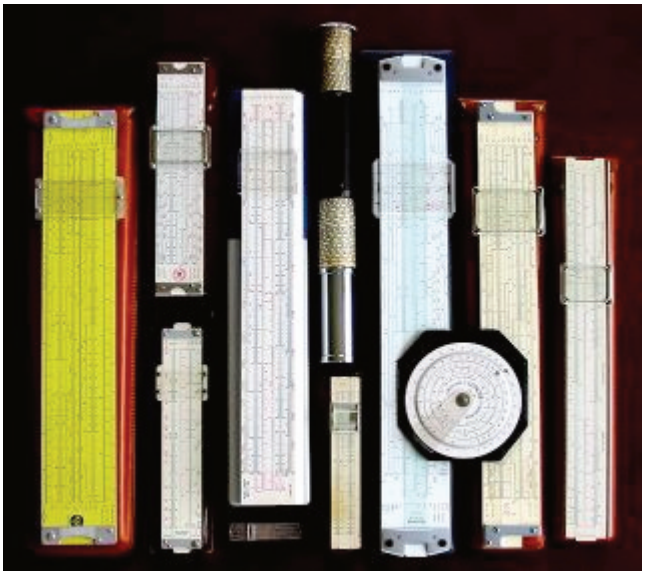
John Napier in 1617 introduced a calculation aid for multiplication, called Napier's Bones. They consist of a set of wooden rods, each marked with a counting number at the top, and multiples of that number down the lengths of the rods. When aligned against the row of multiples as shown in the photo below, any multiple of the top number can be read off from right to left by adding the digits in each parallelogram in the appropriate row. Multiplication is thus reduced to addition.



Napier's Bones – An aid to multiplication, they reduce the problem to one of addition. For example, consider the bones shown here. In order to multiply 6 (horizontal) with 96 (adjacent vertical rods), look at the four cells in the intersection. By adding the numbers in the diagonal cells, from left to right, we compute the answer. (The first cell, corresponding to the 1s digit, is 6; the middle two cells, corresponding to the 10s digit, are 3 and 4, which sum to 7; the next cell, corresponding to the 100s digit is 5; so 6×96=576)
Source: http://www.sciencemuseum.org.uk

Slide Rule

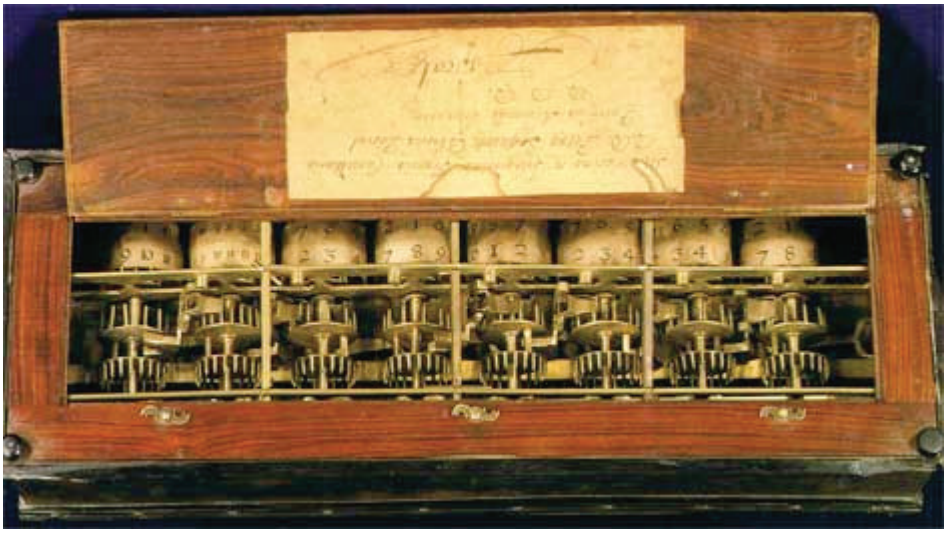
With a goal of simplifying calculations, Napier also introduced the logarithm, which was used in the first slide rule developed by Reverend William Oughtred in approximately 1622. Oughtred also was the first to use the "x" as the symbol for multiplication. Eric Marcott has an excellent website devoted to the slide rule, including operating instructions for various models.



Collection of Slide Rules
Source: http://www.sliderule.ca/index.shtml

Pascalene adder

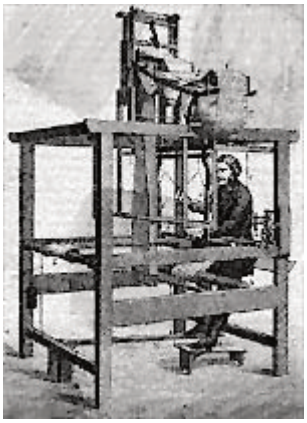
Several automatic mechanical "calculators" were built in the 1600s, including the Schickard implementation of Napier's Bones, the Pascalene automatic adder, and the Liebniz automatic multiplier. Each of these devices was considered an "**analog**" device.



Pascalene Adder
Source: http://history-computer.com

1.2 Early digital computational devices





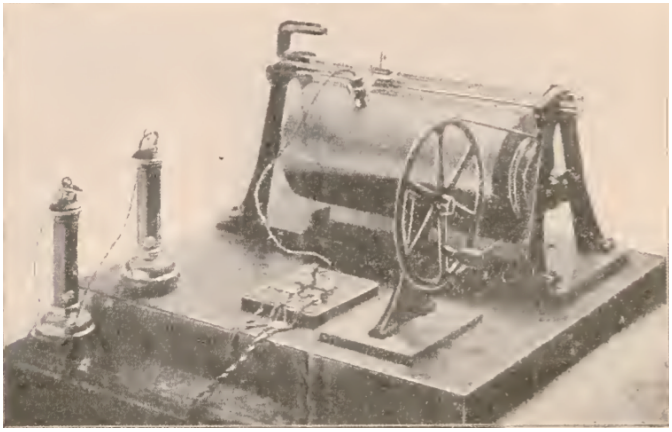
Jacquard Loom

Alternatively, most modern computational devices are "**digital**". One of the earliest implementations of a digital system is attributed to Joseph-Marie Jacquard of France in 1801, the Jacquard Loom. He used a punched card to control the weaving actions of a loom, which introduced much more intricate patterns in woven cloth. Jacquard's approach was a variation on the original punched-card design of Jacques de Vaucanson in 1745. de Vaucanson was a toy maker (most famous for his mechanical duck), and his idea of automating the weaving process was not well accepted by weavers (a situation not unlike that of the modern day computer ink and paint process in traditional animation.)

The punched-card idea was adopted later by Charles Babbage in about 1830 to control his Analytical Engine, and later by Herman Hollerith for tabulating the 1890 census. The Babbage Analytical engine (which was never completed by him) was designed to use Jacquard's punched cards to control an automatic calculator, which could make decisions based on the results of previous computations. It was intended to employ several features later used in modern computers, including sequential control, branching, and looping.

An assistant to Babbage was Augusta Ada Lovelace (or Lady Lovelace), the daughter of the English poet Lord Byron, and a mathematician, who created a "program" for the Analytical Engine to compute a mathematical sequence known as Bernoulli numbers. Based on this work, Ada is now credited as being the first computer programmer and, in 1979, a modern programming language was named ADA in her honor.
From: http://www.agnesscott.edu/lriddle/women/love.htm

In 1878, Oberlin Smith devised a crude magnetic recording device made of a silk thread covered with steel dust. In theory, when exposed to a magnetic field, the steel dust particles would align with the magnet, creating a digital pattern. Smith applied for a patent, but never followed through with the application. He concluded that he wouldn't be able to establish a useful pattern on the strings, published his results in 1888, but dropped his investigations.



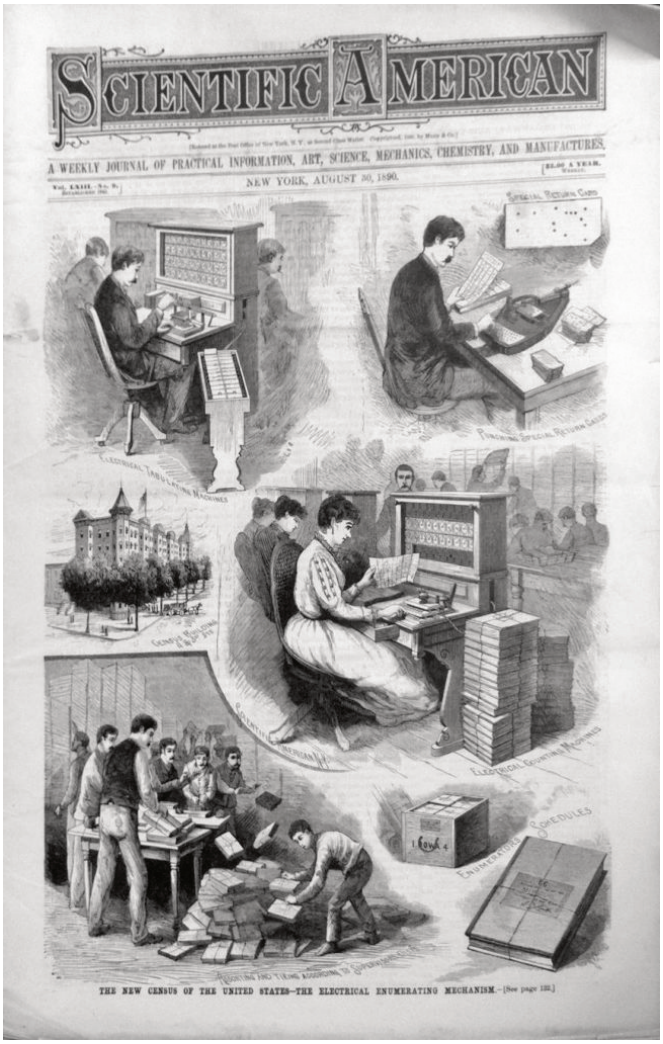
Telegraphone

In 1898, inventor Valdemar Poulsen of Denmark filed a patent for a "…method of, and apparatus for, effecting the storing up of speech or signals by magnetically influencing magnetisable [sic] bodies". His idea was that a wire, when touched with an electromagnet at different points and times, would store a signal that later could be retrieved to recover the same energy that caused the magnetization in the first place. He developed his idea as a "telephone answering machine" called the Telegraphone and started a company to market it. Another of Poulsen's devices can be considered to be the original version of the hard disk. It consisted of a 4.5 inch diameter steel disk with a raised spiral on the surface which was traced by the electromagnet as the disk rotated, magnetizing the disk in the same fashion as the wire.[1]

Further contributions to magnetic recording were few, until Fritz Pfleumer developed the magnetic tape, which was a strip of paper covered with magnetic dust (the first paper tape used was covered with high grade ferric oxide barn paint (rust red), and a cloud of red dust sprayed the air as the tape was used). The German General Electric company bought the patents from Pfluemer and marketed the first true tape recorder, the Magnetophon (meaning "tape recorder" in French) in 1936.

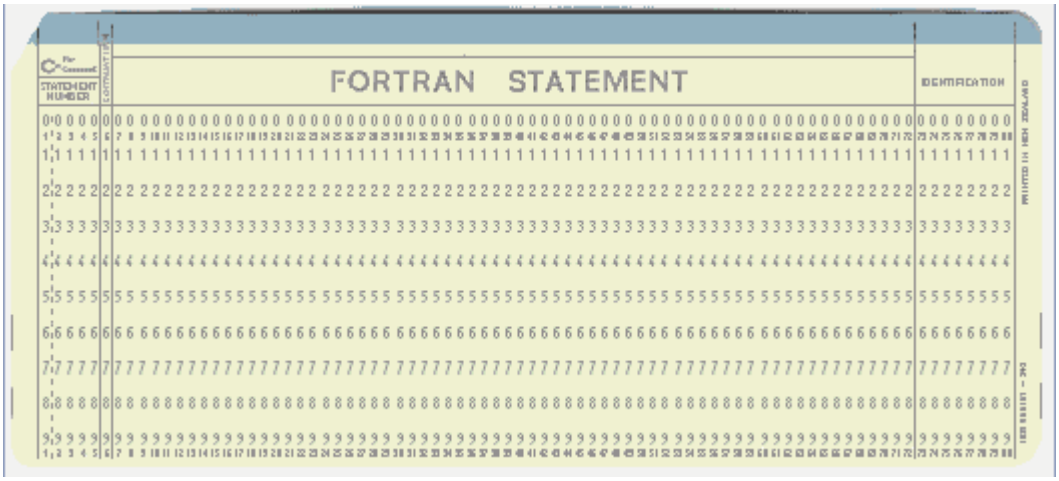
The U.S. Census Bureau was concerned about the difficulty of tabulating the 1890 census. One of its statisticians, Herman Hollerith, envisioned a machine that could automate the process, based on an idea similar to that used in the Jacquard Loom. Hollerith designed punches for his system, which he called the Hollerith Electric Tabulating System. A pin would go through a hole in the census card to make an electrical connection with mercury placed beneath. The resulting electrical current activated a mechanical counter and the information would be tabulated. The tabulating system was featured in an 1890 issue of ?Scientific American magazine.

1. Reference: http://www.computerhistory.org/storageengine/poulsen-records-voice-on-magnetic-wire/;
Image source: Popular Science Monthly, May-Oct 1901, page 414



1890 Scientific American cover

The 80 column punch card introduced by Hollerith in 1928 became the standard input medium for computers until the late 1970s when interactive systems became usable. It was sized at 7 3/8 inches wide by 3 1/4 inches high by .007 inches thick. Prior to 1929, this was a standard size for many U.S. banknotes, and Hollerith apparently chose it so that he could store cards in boxes made for the Treasury Department.

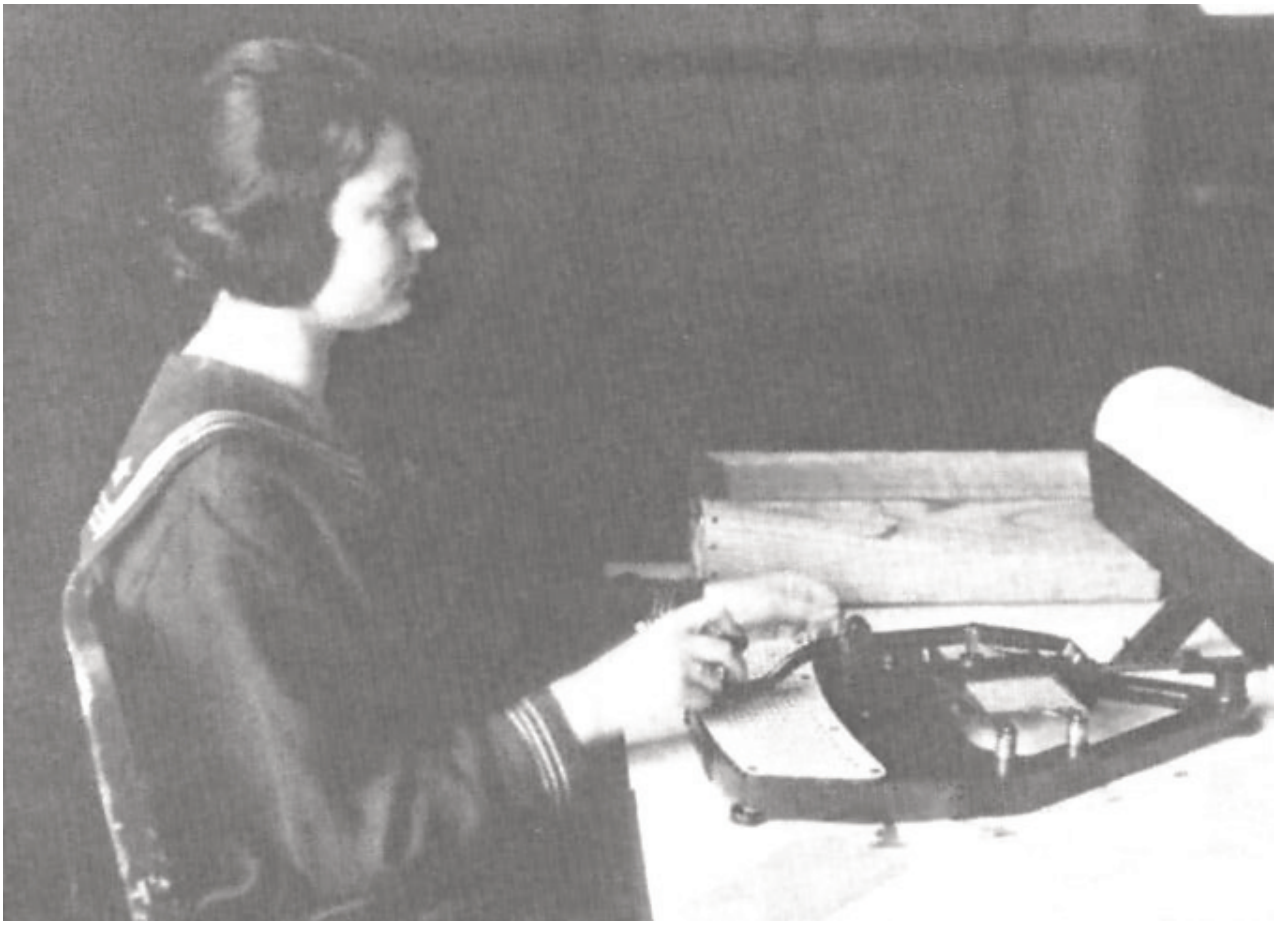


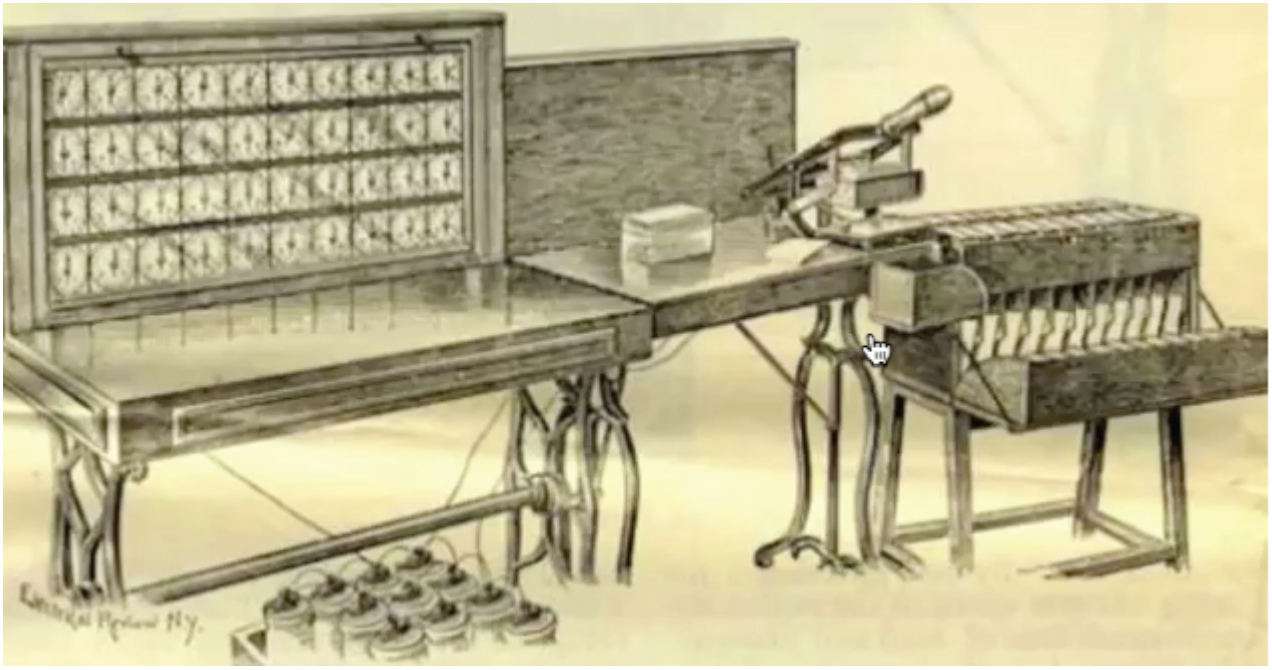
"IBM" Card

What became known as the "IBM card" was the source of a popular phrase which became the topic for a great article by Steven Lubar of the Smithsonian in 1992, titled "*Do not fold, spindle or mutilate: A cultural history of the punch card*."[2]

Hollerith obtained over 30 patents for his research, but he was not a marketer. He felt he had a choke hold on the census tabulating machine, and he charged the Census Bureau more than it would have cost to do it by hand. As a result, they developed, and in fact patented their own version of the machine. Hollerith almost closed the doors on his company, but he was able to attract a brilliant business mind, Thomas J. Watson, to run it, and his company survived; it would later become International Business Machines (IBM).

2. "Do Not Fold, Spindle or Mutilate: A Cultural History of the Punch Card", Steven Lubar, Journal of American Culture, Volume 15, ?Issue 4, pages 43–55, Winter 1992





The Hollerith Tabulating Machine

Definitions:

Analog: relating to, or being a device in which data are represented by continuously variable, measurable, physical quantities, such as length, width, voltage, or pressure; a device having an output that is proportional to the input.

Digital: A description of data which is stored or transmitted as a sequence of discrete symbols from a finite set, most commonly this means binary data represented using electronic or electromagnetic signals.

Ref: http://dictionary.com

http://www.columbia.edu/acis/history/jacquard.html

http://www.swarthmore.edu/Humanities/pschmid1/essays/pynchon/vaucanson.html

http://www.cs.uiowa.edu/~jones/cards/history.html

?http://www.computerhistory.org/revolution/punched-cards/2

1.3 Electronic devices



The turn of the century saw a significant number of electronics-related contributions. One of the most significant was the vacuum tube, invented by Lee de Forest in 1906. It was an improvement on the Fleming tube, or Fleming valve, introduced by John Ambrose Fleming two years earlier. The **vacuum tube** contains three components: the anode, the cathode and a control grid. It could therefore control the flow of electrons between the anode and cathode using the grid, and could therefore act as a switch or an amplifier. A PBS special on the history of the computer used monkeys (the cathode) throwing pebbles (the electrons) through a gate (the grid) at a target (the anode) to explain the operation of the triad tube.

Movie 1.1 Simulation of a Vacuum tube

https://osu.pb.unizin.org/
graphicshistory/wp-content/
uploads/sites/45/2017/04/
monkeysVIDEO_T1-1.m4v

with Host Ira Flatow, from PBS
"Transistorized!"
http://www.pbs.org/transistor/
science/events/vacuumt.html

> http://www.nobel.se/physics/educational/integrated_circuit/history/
> http://www.pbs.org/transistor/album1/addlbios/deforest.html

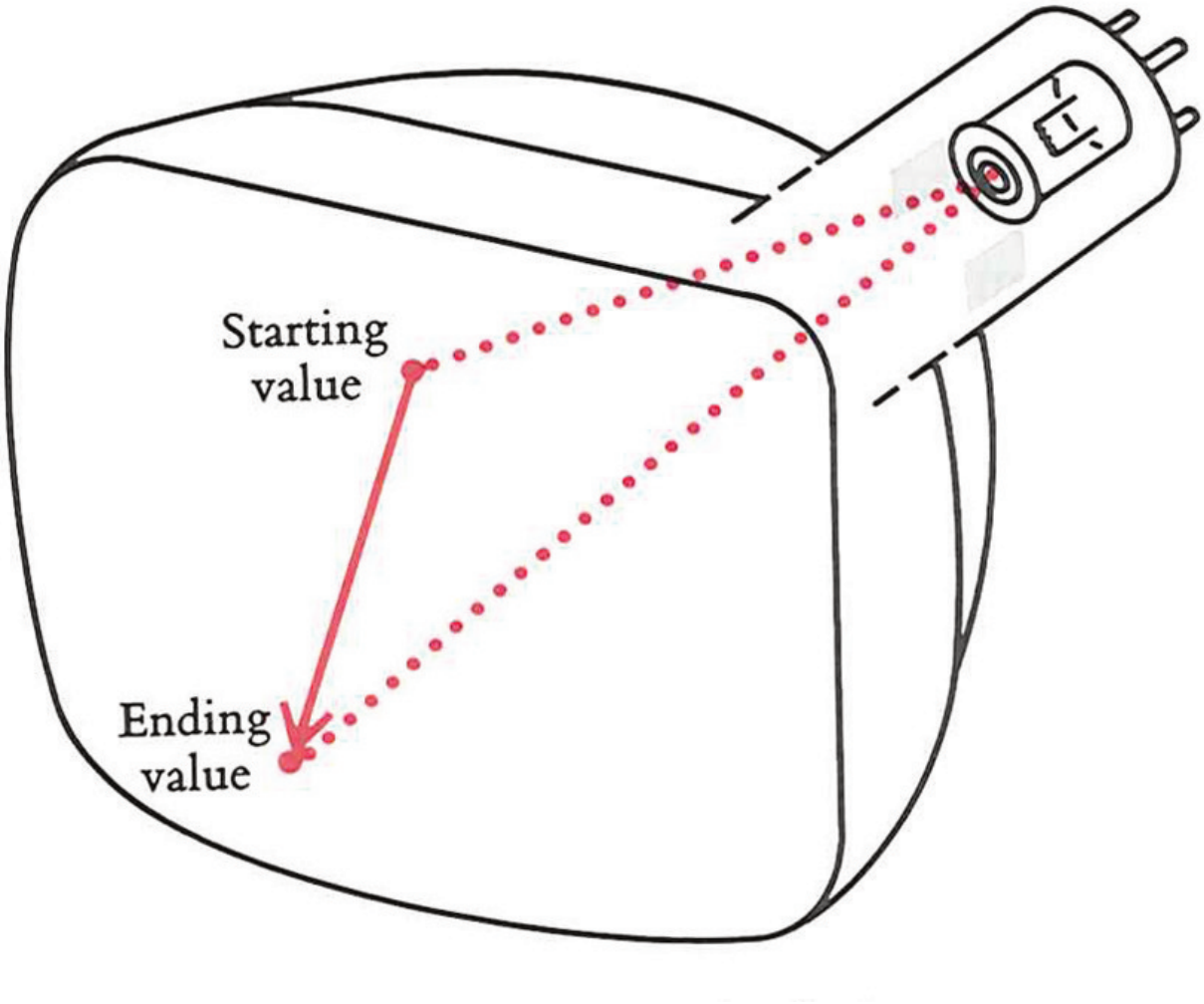
Engineers were interested in the functionality of the vacuum tube, but were intent on discovering an alternative. Much like a light bulb, the vacuum tube generated a lot of heat and had a tendency to burn out in a very short time. It required a lot of electricity, and it was slow and big and bulky, requiring fairly large enclosures. For example, the first digital computer (the ENIAC) weighed over thirty tons, consumed 200 kilowatts of electrical power, and

contained around 19,000 vacuum tubes that got very hot very fast, and as a result constantly burned out, making it very unreliable.



Vacuum tube and transistor

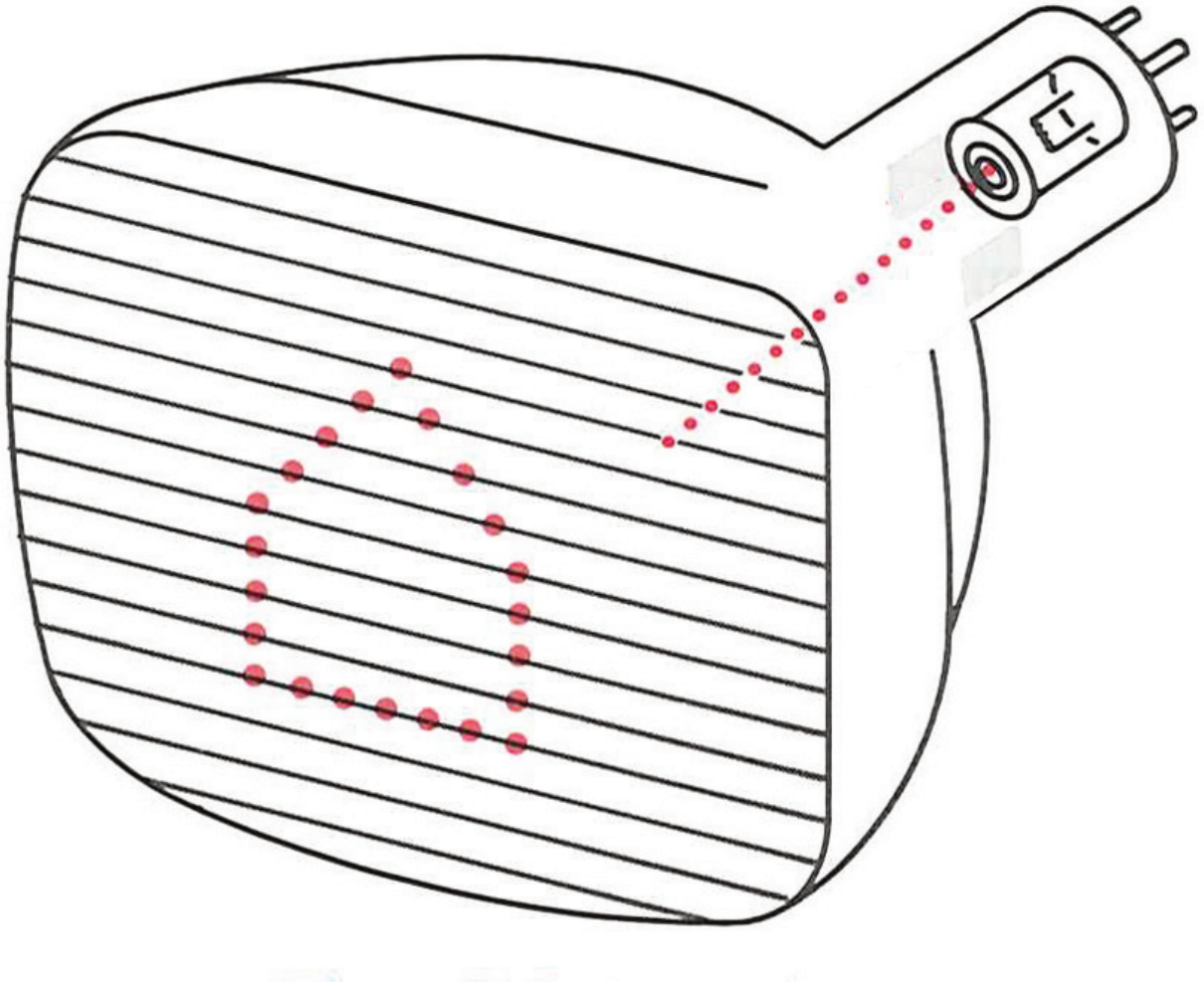
A special kind of vacuum tube was invented in 1885. Called the **Cathode Ray Tube** (CRT), images are produced when an electron beam generated by the cathode strikes a phosphorescent anode surface. The practicality of this tube was shown in 1897, when German scientist Ferdinand Braun introduced a CRT with a fluorescent screen, known as the cathode ray oscilloscope. The screen would emit a visible light when struck by a beam of electrons.



Cathode Ray Tube – Vector display

This invention would result in the introduction of the modern television when Idaho native **Philo Farnsworth** introduced the image dissector in 1927, and the first 60 line "**raster-scanned**" image was shown (it was an image of a dollar sign.) Farnsworth has been called one of the greatest inventors of all times, but he suffered for a long period of time in obscurity because of an unfortunate set of circumstances. RCA challenged the patents that Farnsworth received in 1930 for the technology which was the television, and although he won the litigation, it took so long that his patents expired and RCA maintained a public relations campaign to promote one of their engineers as the actual inventor (see sidebar below.)

Variations of the CRT have been used throughout the history of computer graphics, and it was the graphics display device of choice until the LCD display was introduced 100 years later. The three main variations of the CRT are the vector display, a "**storage tube**" CRT (developed in 1949), and the **raster** display.



Cathode Ray Tube – Raster display

For more information: http://entertainment.howstuffworks.com/tv3.htm

The following text is from Time Magazine's accounting of the 100 great inventors of all time:

> "As it happens, [Vladamir] Zworykin had made a patent application in 1923, and by 1933 had developed a camera tube he called an Iconoscope. It also happens that Zworykin was by then connected with the Radio Corporation of America, whose chief, David Sarnoff, had no intention of paying royalties to [Philo]Farnsworth for the right to manufacture television sets. "RCA doesn't pay royalties," he is alleged to have said, "we collect them."
>
> And so there ensued a legal battle over who invented television. RCA's lawyers contended that Zworykin's 1923 patent had priority over any of Farnsworth's patents, including the one for his Image Dissector. RCA's case was not strong, since it could produce no evidence that in 1923 Zworykin had produced an operable television transmitter. Moreover, Farnsworth's old [high school] teacher, [Justin]

Tolman, not only testified that Farnsworth had conceived the idea when he was a high school student, but also produced the original sketch of an electronic tube that Farnsworth had drawn for him at that time. The sketch was almost an exact replica of an Image Dissector.

In 1934 the U.S. Patent Office rendered its decision, awarding priority of invention to Farnsworth. RCA appealed and lost, but litigation about various matters continued for many years until Sarnoff finally agreed to pay Farnsworth royalties.

But he didn't have to for very long. During World War II, the government suspended sales of TV sets, and by the war's end, Farnsworth's key patents were close to expiring. When they did, RCA was quick to take charge of the production and sales of TV sets, and in a vigorous public-relations campaign, promoted both Zworykin and Sarnoff as the fathers of television."
Ref: http://www.time.com/time/time100/scientist/profile/farnsworth.html? and
http://www.farnovision.com/chronicles/

The specter of World War II, and the need to calculate complex values, e.g. weapons trajectories and firing tables to be used by the Army, pushed the military to replace their mechanical computers, which were error prone. Lt. Herman Goldstine of the Aberdeen Proving Grounds contracted with two professors at the University of Pennsylvania's Moore School of Engineering to design a digital device. Dr. John W. Mauchly and J. P. Eckert, Jr., professors at the school, were awarded a contract in 1943 to develop the preliminary designs for this electronic computer. The ENIAC (Electronic Numerical Integrator and Computer) was placed in operation at the Moore School in 1944. Final assembly took place during the fall of 1945, and it was formally announced in 1946.

The ENIAC was the prototype from which most other modern computers evolved. All of the major components and concepts of today's digital computers were embedded in the design. ENIAC knew the difference in the sign of a number, it could compare numbers, add, subtract, multiply, divide, and compute square roots. Its electronic accumulators combined the functions of an adding machine and storage unit. No central memory unit existed, and storage was localized within the circuitry of the computer.

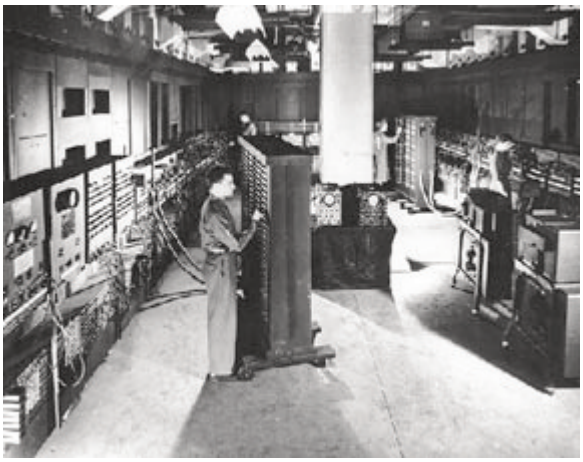


Image: Popular Science, Apr. 1946 Page 84

The primary aim of the designers was to achieve speed by making ENIAC as all-electronic as possible. The only mechanical elements in the final product were actually external to the calculator itself. These were an IBM card reader for input, a card punch for output, and the 1,500 associated relays.

An interesting side note occurred after the delivery of the prototype to the military, when Eckert and Mauchly formed a company to commercialize the computer. Disputes arose over who owned the patents for the design, and the professors were forced to resign from the faculty of the University of Pennsylvania. The concept of "technology transfer" from the university research labs to the private sector, which is common today, had no counterpart in the late 1940s and even into the 1980s.

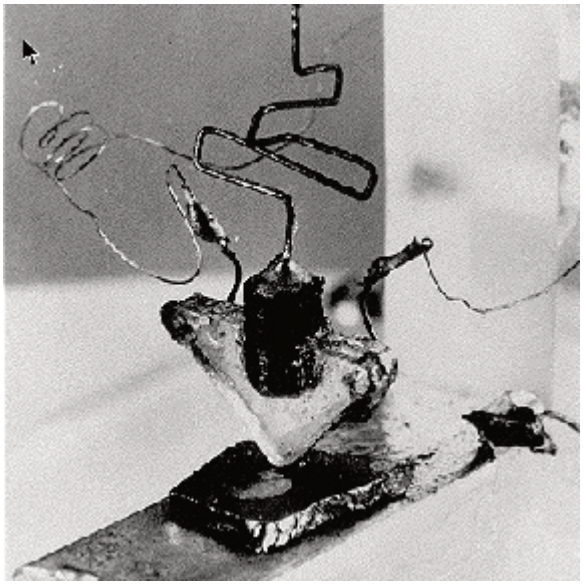
The revolution in electronics can be traced to the tube's successful replacement with the discovery of the transistor[1] in 1947 by a team at Bell Labs (Shockley, Bardeen and Brattain). Based on the semiconductor technology, the transistor, like the vacuum tube, functioned as a switch or an amplifier. Unlike the tube, the transistor was small, had a very stable temperature, was fast and very reliable. Because of it's size and low heat, it could be arranged in large numbers in a small area, allowing the devices built from it to decrease significantly in size.

The transistor still had to be soldered into the circuits by hand, so the size was still limited. The ubiquitous presence of the transistor resulted in all sorts of mid-sized devices, from radios to computers that were introduced in the 1950s.

> The ENIAC patents (which covered basic patents relating to the design of electronic digital computers) were filed in 1947 by John W. Mauchly and J. Presper Eckert arising from the work conducted at the Moore School of Electrical Engineering at the University of Pennsylvania. In 1946, Eckert and Mauchly left the Moore School and formed their own commercial computer enterprise, the Electronic Control Company, which was later incorporated as the Eckert-Mauchly Computer Corporation. In 1950 Remington Rand acquired Eckert-Mauchly and the rights to the ENIAC patent eventually passed to Sperry Rand as a result of a merger of the Sperry Corporation and Remington Rand in 1955. After the patent was granted to the Sperry Rand Corporation in 1964, the corporation demanded royalties from all major participants in the computer industry. Honeywell refused to cooperate, so Sperry Rand then filed a patent infringement suit against Honeywell in 1967. Honeywell responded in the same year with an antitrust suit charging that the Sperry Rand-IBM cross-licensing agreement was a conspiracy to monopolize the computer industry, and also that the ENIAC patent was fraudulently procured and invalid.
>
> Ref: Charles Babbage Institute, Honeywell vs. Sperry Litigation Records, 1947-1972; Also see a first-person accounting by Charles McTiernan in an Anecdote article in the Annals of the History of Computing

The next breakthrough which was credited with spawning an entire industry of miniature electronics came in 1958 with the discovery (independently by two individuals) of the **integrated circuit**. The integrated circuit (IC, or Chip), invented by Jack St. Clair Kilby of Texas Instruments (later winner of the Nobel Prize in physics and one of the designers of the TI hand-held calculator) and Robert Noyce of Fairchild Electronics (later one of the founders of Intel), allowed the entire circuit (transistors, capacitors, resistors, wires, …) to be made out of silicon on a single board.

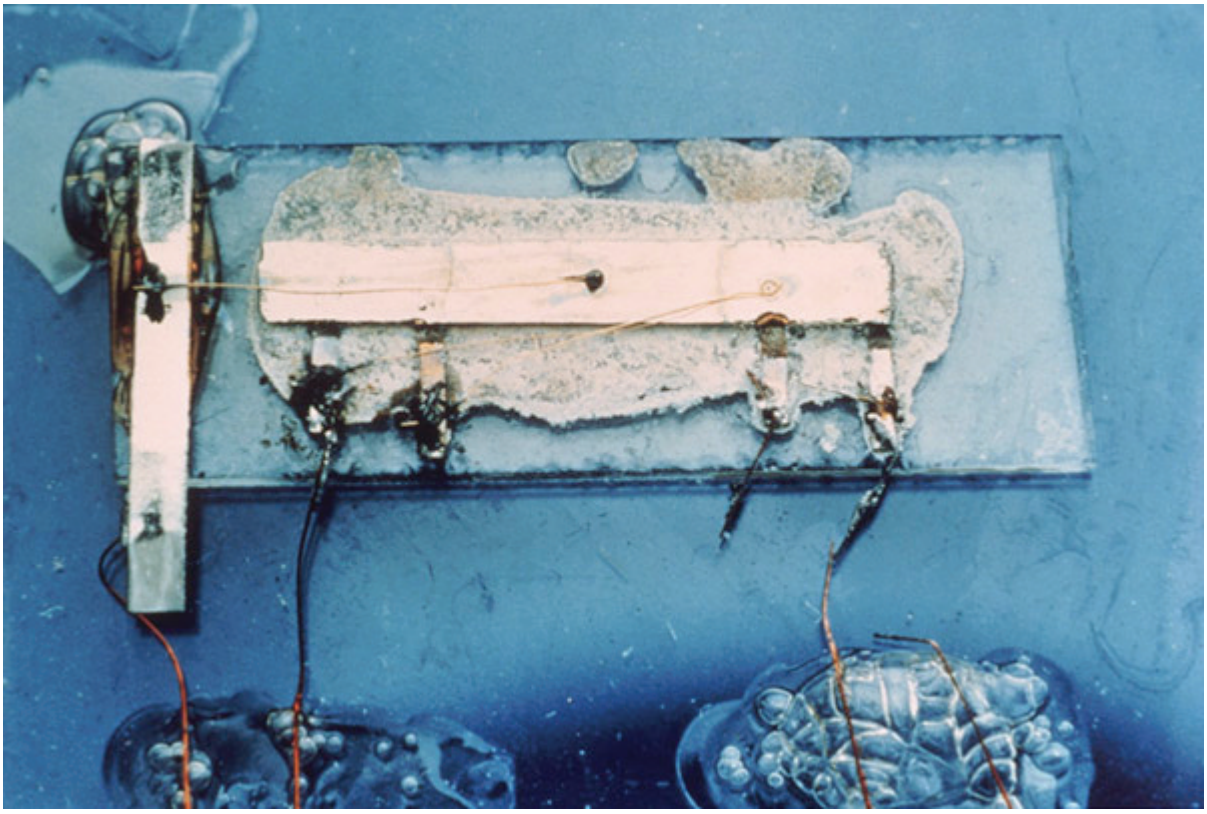
1. Reference: http://www.porticus.org/bell/belllabs_transistor.html



The earliest transistor (source: AT&T Bell Labs)

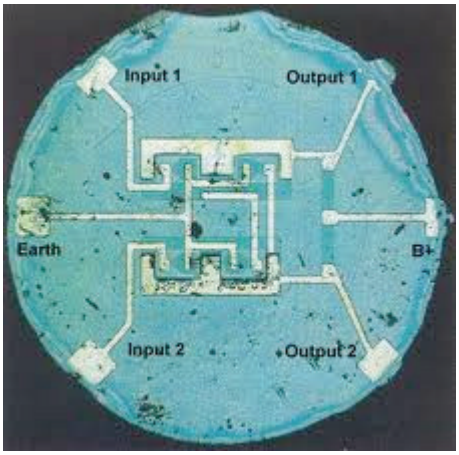
In the design of a circuit, connections must be of primary importance, so that the electrical current can traverse the entire circuit. In early circuit construction, several problems contributed to failure. First, manual assembly of huge numbers of tiny components resulted in many faulty connections. The second problem was one of size: if the components are too large or connections too long, electric signals can't travel fast enough through the circuit.

In 1958 Kilby came up with his solution to the miniaturization problem: make all the components and the chip out of the same block (monolith) of semiconductor material. Making all the parts out of the same block of material and adding the metal needed to connect them as a layer on top of it eliminated the need for individual discrete components. Circuits could be made smaller and the manual assembly part of the manufacturing process could be eliminated.



Kilby "monolithic" integrated circuit (source: Texas Instruments)

Noyce's solution, introduced six months later, solved several problems that Kilby's circuit had, mainly the problem of connecting all the components on the monolith. His solution was to add the metal as a final layer, and then remove enough to provide the desired flow of electrons; thus the "wires" needed to connect the components were formed. This made the integrated circuit more suitable for mass production.



Noyce "unitary" IC (source: Fairchild Semiconductor)

http://www.nobel.se/physics/educational/integrated_circuit/history/

http://www.computer-museum.org/collection/ti-icphoto.html
http://www.chiphistory.org/fairchild_ic.htm

The Encyclopedia of Computer Science identifies the Atanasoff–Berry Computer (ABC) as the first electronic digital computing device. Conceived in 1937, the machine was not programmable, being designed only to solve systems of linear equations. It was successfully tested in 1942. It was the first computing machine to use electricity, vacuum tubes, binary numbers and capacitors. The capacitors were in a rotating drum that held the electrical charge for the memory.

However, its intermediate result storage mechanism, a paper card writer/reader, was unreliable, and when inventor John Vincent Atanasoff left Iowa State College for World War II assignments, work on the machine was discontinued. The ABC pioneered important elements of modern computing, including binary arithmetic and electronic switching elements, but its special-purpose nature and lack of a changeable, stored program distinguish it from modern computers. The computer was designated an IEEE Milestone in 1990.

Atanasoff and Clifford Berry's computer work was not widely known until it was rediscovered in the 1960s, amidst conflicting claims about the first instance of an electronic computer. At that time, the ENIAC was considered to be the first computer in the modern sense, but in 1973 a U.S. District Court invalidated the ENIAC patent and concluded that the ENIAC inventors had derived the subject matter of the electronic digital computer from Atanasoff. The judge stated "Eckert and Mauchly did not themselves first invent the automatic electronic digital computer, but instead derived that subject matter from one Dr. John Vincent Atanasoff."

Chapter 2: The emergence of graphics technology

The emergence of graphics technology

The late 1940s and early 1950s saw rapid developments in hardware and software, and an emerging interest on the part of the federal government in visual representation. The computer graphics discipline was born.



3D Reconstruction of Moon-rise Over Newark Earthworks, http://indianmounds.wordpress.com (2010)

2.1 Whirlwind and SAGE



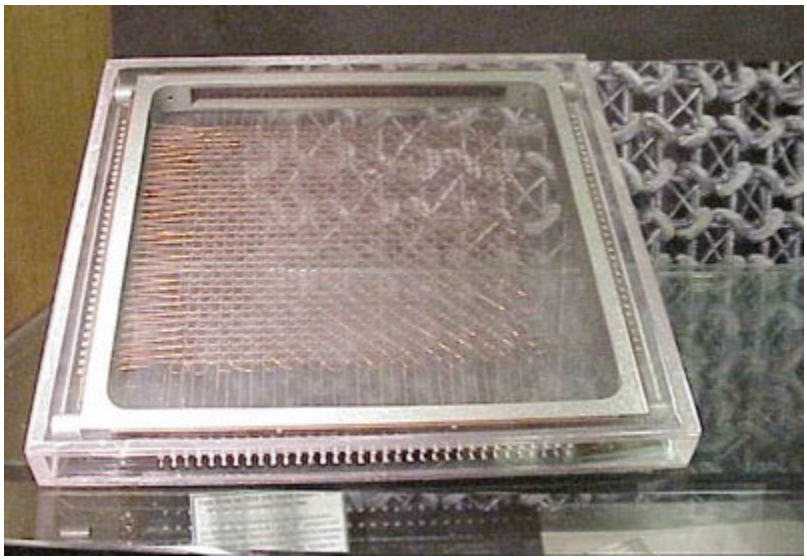
The evolution of the digital computer continued with the **Whirlwind** computer. Development of the Whirlwind began in 1945 under the leadership of Jay Forrester at MIT, as part of the Navy's Airplane Stability and Control Analyzer (ASCA) project. The system was proposed in order to provide a "programmable" flight simulation environment and was first demonstrated in 1951. This was not the first digital computer, but it was the first computer capable of displaying real time text and graphics, using a large oscilloscope screen.



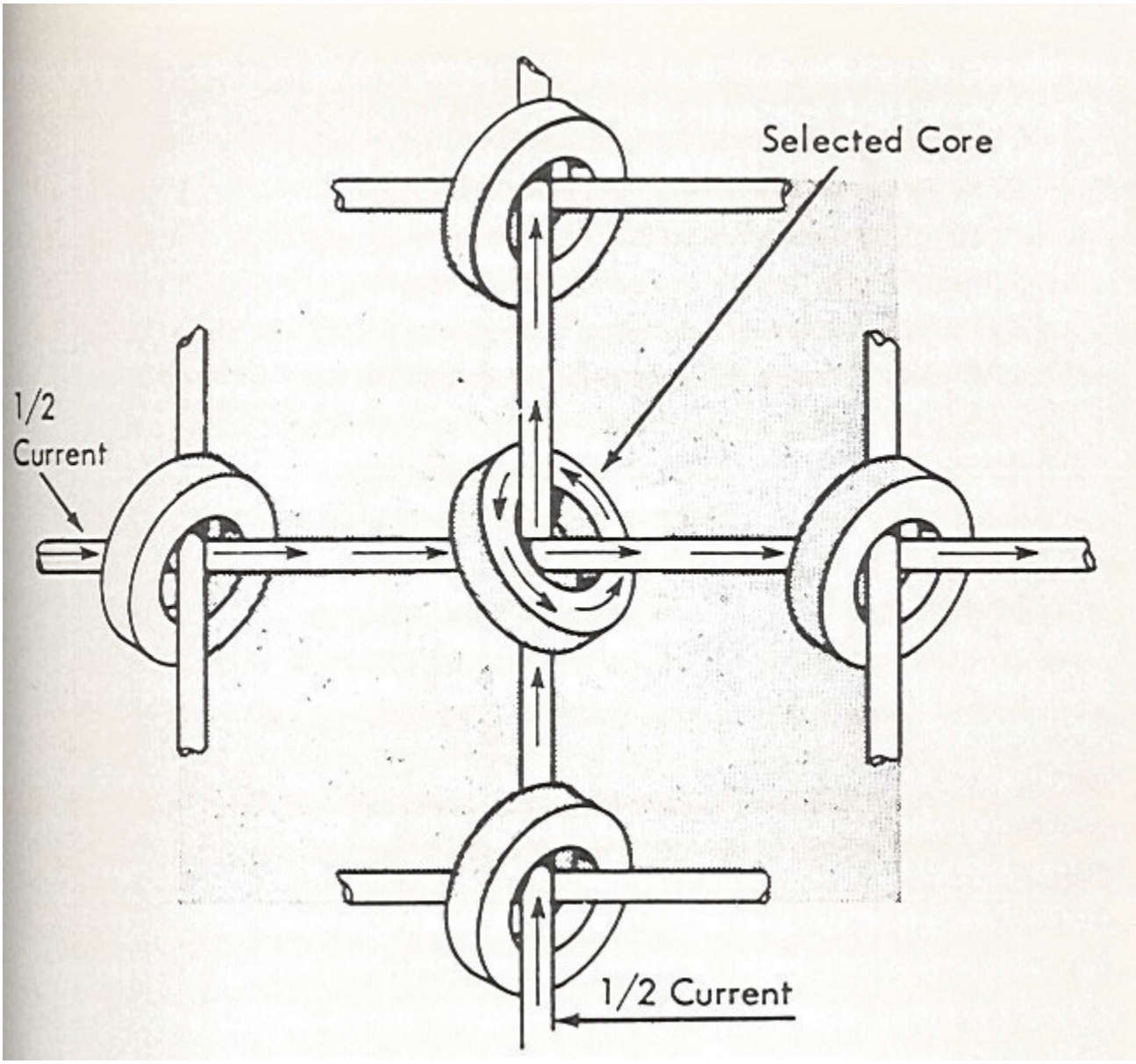
Pictures used with the permission of The MITRE Corporation. ?Copyright – The MITRE Corporation. All Rights Reserved.

Whirlwind received positional data related to an aircraft from a radar station in Massachusetts. The Whirlwind programmers had created a series of data points, displayed on the screen, that represented the eastern coast of Massachusetts, and when data was received from radar, a symbol representing the aircraft was superimposed over the geographic drawing on the screen of a CRT. Robert Everett (who later became CEO of Mitre Corporation) designed an input device, which was called a light gun or light pen, to give the operators a way of requesting identification information about the aircraft. When the light gun was pointed at the symbol for the plane on the screen, an event was sent to Whirlwind, which then sent text about the plane's identification, speed and direction to also be displayed on the screen.

As a result of performance and expense, Forrester opted not to use new mercury delay line memory or electrostatic storage tubes. Instead he investigated a magnetic ceramic called Deltamax, which could be subjected to magnetic pulses which would result in a change of state that could remain indefinitely. Called **core memory**, each component was a donut shaped metal that had two electrical wires strung through it. Neither was strong enough in power to change the state of the magnetism, but together they were. Thus it was a randomly addressable storage and access medium.

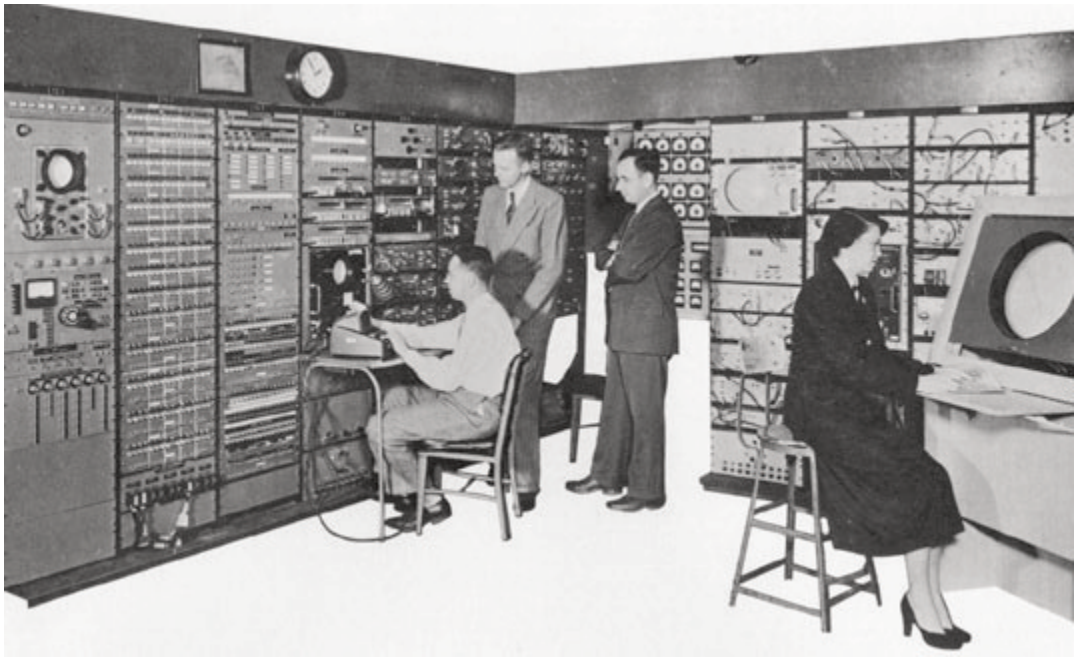


A core memory component out of the Whirlwind computer. This bank has 32×32 bits and is approximately 14 inches square. Source: Mitre Corporation



How core memory works

The Whirlwind project was very expensive and made up the bulk of the Office of Naval Research budget. As a result, it became the target of congressional budget cutters, who threatened to reduce the allocation from $1.15M to $0.25M in 1951. Through intense lobbying by MIT, the Whirlwind computer was ultimately adopted by the U.S. Air Force for use in its new **SAGE** (Semi-Automatic Ground Environment) air defense system, which became operational in 1958 with more advanced display capabilities.
http://www.mitre.org/about/sage.html



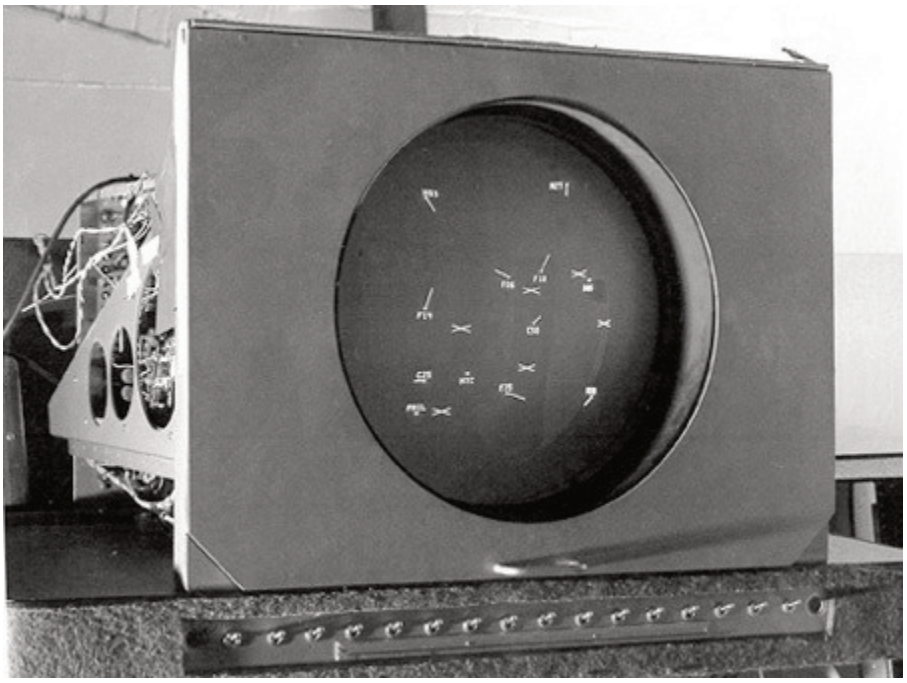
The Whirlwind computer at MIT (circa 1951). In this photo, Stephen Dodd, Jay Forrester, Robert Everett, and Ramona Ferenz (seated at the CRT display) convene at the Whirlwind I test control in the Barta Building at MIT. Source: Mitre Corporation

The Deltamax core was replaced by faster ferrite core memory in 1953. RCA applied for the contract to manufacture SAGE but it ultimately was awarded to IBM, who placed two Whirlwind computers in each of the 23 Air Force SAGE centers. Due to the launch of Sputnik, the Air Force became less concerned about long range bombers, and more concerned about intercontinental ballistic missiles, and it was phased out. The last of the Whirlwind-based SAGE computers was shut down in 1983, giving the Whirlwind a record for practical operational longevity among early digital computers.



SAGE demonstrated pioneering solutions to the problem of the user interface. The system displayed extremely large amounts of information to its operators using the then-new cathode ray tube; operators could then obtain additional information on aircraft tracks by selecting them with a light gun. Similar techniques are still in use today.

SAGE



Vector display with geographical reference marks. A Whirlwind I computer generates and displays aircraft positions and auxiliary information on the console. (The direction and length of the vector indicate the aircraft's direction and speed.) The operator uses a row of switches below the scope face to choose the information (e.g., vectors, identification, and track numbers) to be displayed. In this photo, geographical reference information has been superimposed on the display in response to a switch control

Besides the innovations related to computing hardware and software technology, the Whirlwind and SAGE projects helped to open the door to the computer graphics discipline by providing the CRT as a viable display and interaction interface, and introduced the light pen as an important input device. The Whirlwind and SAGE projects are documented in a 1999 book published by the National Academies Press, titled *Funding a Revolution: Government Support for Computing Research* (details are on page 91ff in Chapter 6). It can be read and/or downloaded at https://www.nap.edu/read/6323/chapter/1

Movie 2.1 On Guard! (1956)

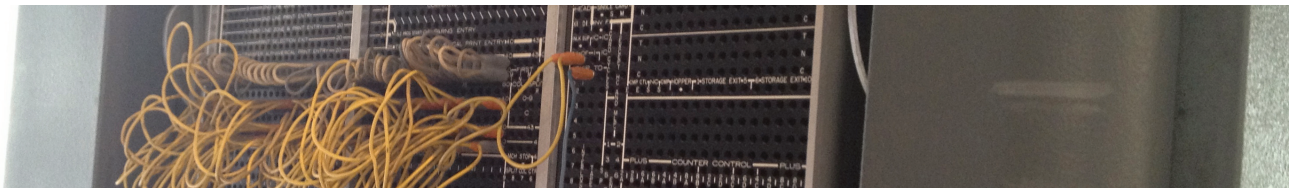


http://www.youtube.com/watch?v=Kpahs3MAEDc

The first half of the movie "On Guard!" produced by IBM, is about the SAGE project. The second half covers the process of making computers flight-worthy.

MIT licensed the technology for core memories to several computer companies – IBM, Univac, RCA, General Electric, Burroughs, NCR, Lockheed, and Digital Equipment Corporation, and memory suppliers, including Ampex, Fabri-TEk, Electronic Memory & Magnetics, Data Products, General Ceramics, and Ferroxcube. (National Academy Press)

2.2 Programming and Artistry



Although the hardware developments of the 1950s were extremely important to the CG discipline, there were also many innovations with respect to software that have allowed us to move rapidly forward to where we are today. For example, in the early development of the **ENIAC**, it was determined that the value of a digital computer was that you could "program" it to accomplish tasks, and then reprogram it to do something completely different.



Grace Hopper

Grace Hopper was a programmer on the Harvard Mark I and Mark II projects, and was hired by the Eckert and Mauchly Computer Company in 1949 to program the commercial version of the ENIAC. She experimented with the concept of software reusability, and published a paper in 1952 which laid out the general concepts of language translation and compilers. General computer languages were thus enabled, which created an environment that encouraged a significantly larger universe of computer users and applications. Hopper became a Commodore in the U.S. Navy in 1983 (a rank that was converted to an Rear Admiral – Lower Half in 1985), and died in 1992.[1]

http://www.cs.yale.edu/homes/tap/Files/hopper-story.html

In 1954 John Backus of IBM proposed the FORTRAN programming language, which was built around the idea that you could express numerical formulae in the programming language and the compiler could convert it to the base level instructions of the machine on which it resided.

In 1960 John McCarthy of MIT published a landmark paper in the Communications of the ACM on recursive functions in programming, in which he introduced a new programming language called LISP (for "List Processing"). The language contained a handful of simple operators and a functional notation, all built around

1. On November 22, 2016, Grace Hopper was posthumously awarded the Presidential Medal of Freedom by President Barack Obama.

a central simple data structure called a *list* for both code and data. (LISP is the language used in the Symbolics graphics computer described in more detail in Section 6.3).

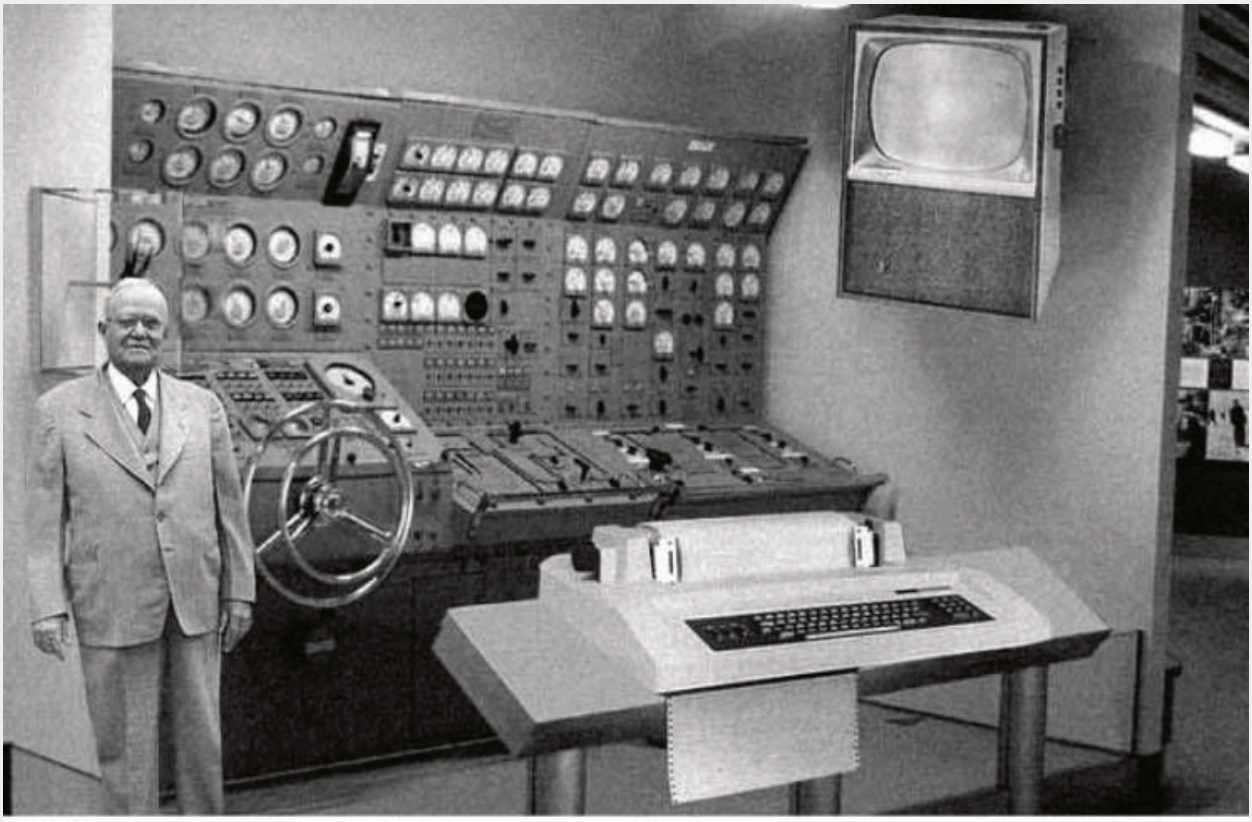
John G. Kemeny and Thomas E. Kurtz invented the language BASIC in 1964 for use at Dartmouth College. This language had a widespread influence on the development of the industry, as they made it freely available to everyone who wanted to learn how to program computers. Many other languages have evolved and been used by programmers in the intervening years.

Hopper, Grace. *The Education of a Computer*. Proceedings of the Association for Computing Machinery Conference (Pittsburgh) May 1952.

John McCarthy: *Recursive Functions of Symbolic Expressions and Their Computation by Machine, Part I*. Communications of the ACM 3(4): 184-195 (1960) *[Note: Part 2 was never published]*

John G. Kemeny and Thomas E. Kurtz. *A Manual for BASIC, the elementary algebraic language designed for use with the Dartmouth Time Sharing System*. Dartmouth College Computation Center. 1964.

John Backus. *The History of FORTRAN I, II, and III*. History of Programming Languages, Association for Computing Machinery, 1981.

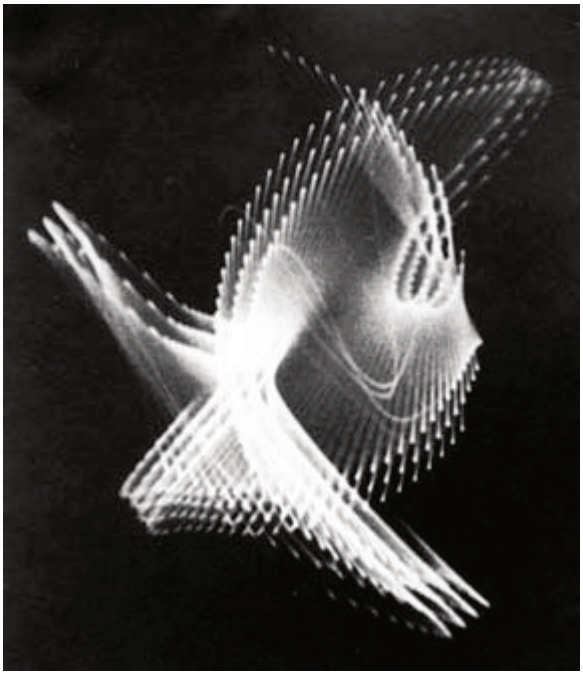


Scientists from the RAND Corporation have created this model to illustrate how a "home computer" could look like in the year 2004. However the needed technology will not be economically feasible for the average home. Also the scientists readily admit that the computer will require not yet invented technology to actually work, but 50 years from now scientific progress is expected to solve these problems. With teletype interface and the Fortran language, the computer will be easy to use.

This photo from the 1954 Modern Mechanics magazine predicted what the home computer might look like 50 years from then. The caption reads *"Scientists from the RAND Corporation have created this*

model to illustrate how a "home computer" could look like in the year 2004. However the needed technology will not be economically feasible for the average home. Also, the scientists readily admit that the computer will require not yet invented technology to actually work, but 50 years from now scientific progress is expected to solve these problems. With teletype interface and the Fortran language, the computer will be easy to use."

The aforementioned "larger universe of computer users" that took advantage of Hopper's early programming innovations included artists and designers, as well as mathematicians and computer engineers. Sometimes the difference between the diverse groups was blurry at best. In the early days of interacting with the new digital computer, often investigations into issues such as complex math formulas or ergonomic design resulted in visual images produced on the computer that have remained in our discipline as contributions to the field of art.

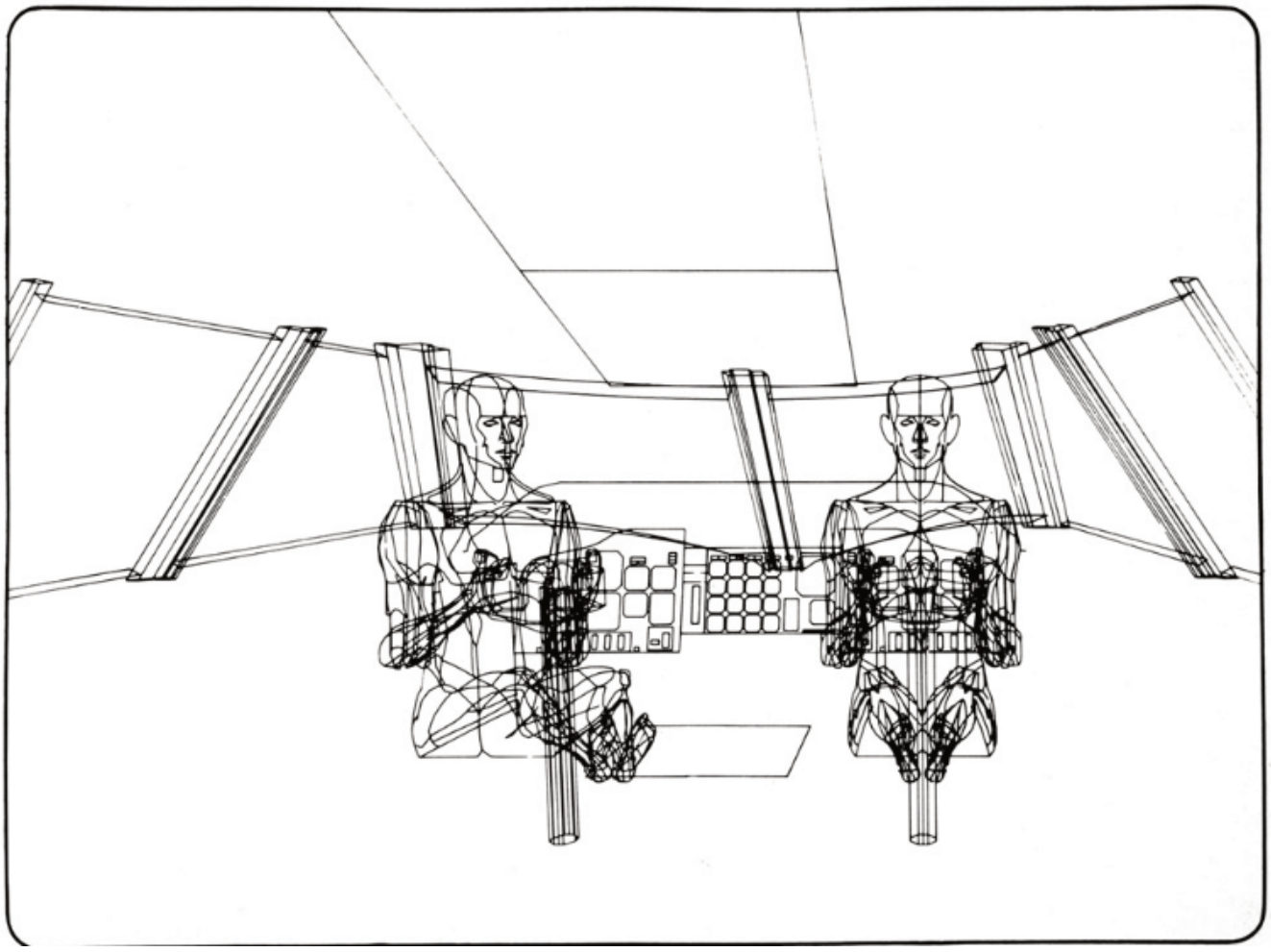


Laposky's Oscillon #4 (source: Electronic Abstractions -Sanford Museum).

For example, **Ben Laposky** was a mathematician and artist from Iowa. In 1950, he created the first graphic images generated by an electronic (in his case, an analog) machine. His electronic oscilloscope imagery was produced by manipulated electronic beams displayed across the fluorescent face of an oscilloscope's cathode-ray tube and then recorded onto high-speed film. He called his oscillographic artworks 'oscillons' and 'electronic abstractions'. The mathematical curves that were created by this method were similar to the Lissajous mathematical wave form. (Another artist working with the same approach was Herbert Franke from Germany. More about Franke can be read in Chapter 9 of this book.)

More about Laposky can be found at http://digitalartmuseum.org/laposky/index.htm

To learn more about Lissajous patterns, go to? http://www.math.com/students/wonders/lissajous/lissajous.html

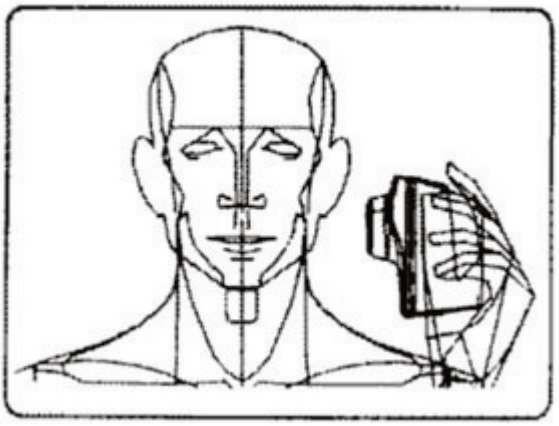


"First Man" – 1968 – (source: Proceedings SPIE 166, 1978)

William Fetter was a graphic designer for Boeing Aircraft Co. and in 1960, was credited with coining the phrase "Computer Graphics" to describe what he was doing at Boeing at the time. (Fetter has said that the terms were actually given to him by Verne Hudson of the Wichita Division of Boeing.)

As Fetter stated in a 1978 interview, "There has been a long-standing need in certain computer graphics applications for human figure simulations, that as descriptions of the human body are both accurate and at the same time adaptable to different user environments." His early work at Boeing was focused on the development of such ergonomic descriptions. One of the most memorable and iconic images of the early history of computer graphics was such a human figure, often referred to as the "Boeing Man", but referred to by Fetter as the "First Man".
(Source: http://courses.washington.edu/eatreun)

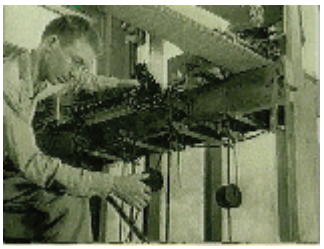
In 1970, Fetter left Seattle to work in Los Angeles, where he created one of the first in-perspective computer graphics TV commercials, a commercial for Norelco. He then moved to Carbondale, Illinois to become the Southern Illinois University Design Department Chairman, working with Buckminster Fuller. Fetter died in 2002.



"Norelco Commercial" – 1970 (source: Proceedings SPIE 166, 1978)



John and James Whitney



John Whitney

John Whitney, Sr. was one of the earliest and most influential of the computer animation pioneers. He came at the problem from the background of film, working with his brother James Whitney[2] on a series of experimental films in the 1940s and 1950s.

His work in this area gave him the opportunity to collaborate with well known Hollywood filmmakers, including Saul Bass.

His earliest computer work used analog devices for controlling images and cameras. After the second world war, Whitney purchased surplus military equipment and modified it to be used in his art making. One such device was an analog mechanism used in military anti-aircraft controllers, the M-5 (and later the M-7). Whitney and his brother converted this device of war into an animation controller, and used it together with a mounted camera as an animation stand.

2. John Whitney's younger brother James was famous in his own right, for work in the traditional animation filmmaking field. William Moritz wrote an interesting article about the younger Whitney (with corrections by the Center for Visual Music) called *Who's Who in Filmmaking: James Whitney* in Sightlines, Vol.19, no.2, Winter 1985/1986.

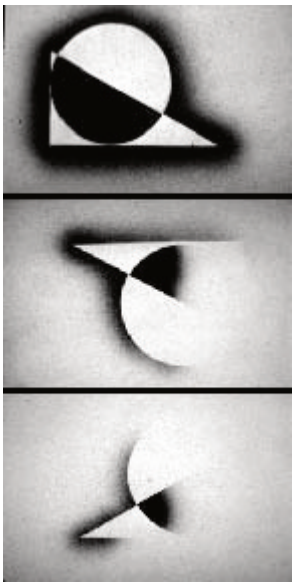


Left: John Whitney Sr. filming from the screen;?Next page: scenes from his animation Spirals, and John Whitney. (Source: Animation World Magazine)

His son John Jr. said the following about his dad's approach:

> I don't know how many simultaneous motions can be happening at once. There must be at least five ways just to operate the shutter. The input shaft on the camera rotates at 180 rpm, which results in a photographing speed of 8 frame/s. That cycle time is constant, not variable, but we never shoot that fast. It takes about nine seconds to make one revolution. During this nine-second cycle the tables are spinning on their own axes while simultaneously revolving around another axis while moving horizontally across the range of the camera, which may itself be turning or zooming up and down. During this operation we can have the shutter open all the time, or just at the end for a second or two, or at the beginning, or for half of the time if we want to do slit-scanning. [3]

Unlike the digital computer which requires the processing of mathematical equations as its input, Whitney's analogue computer had to have its information ready before it was processed, meaning that a template had to be created. The "information" or image source was hi-con **Kodalith** film negatives. When manipulated by the cam machine in a precise orbital motion, with an added movement differential, the result was animation. His insight was to harness the cam and ball integrators (formerly used as dedicated equation solvers for the gun fuse timing) as a source of differential motion.



Scenes from Variations

http://www.siggraph.org/artdesign/profile/whitney/home.html

3. Youngblood, Gene. Expanded Cinema (New York. E.P. Dutton & Company, 1970 (page 210)

After establishing his company Motion Graphics, Inc in 1960, he used his analog devices for the opening to the Hitchcock movie Vertigo in 1961. His company was focused on producing titles for film and television, and was also used in graphics for commercials. But Whitney was far more interested in the use of the technology as an art form, and began a series of collaborations in art making that lasted for years.

Many of these early collaborations revolved around the advancement of the vector graphics device as a viable tool for making art. Whitney received funding from IBM to take a look at the use of IBM equipment in the design of motion. He worked with IBM programmers in the development of a language for extending the computer to the control of graphics devices. This resulted in one of his most famous animations, Permutations, in 1968. Whitney went on to a residency at MIT in the Center for Advanced Visual Studies. Later he utilized the equipment of his son John, Jr., at his commercial company Information International Inc. (III) and created his Matrix III animation; he joined with artist/programmer Larry Cuba with funding from the National Endowment for the Arts and the Judith S. Thomas Foundation to produce what is arguably his second most famous work, Arabesque. In this film, Whitney demonstrated the concepts of "harmonic progression" through the vehicle of Islamic architecture.



John Whitney

Whitney joined the faculty at UCLA and supervised the work of a large number of animation students. Their collaboration, Digital Harmony (also the name of a book he wrote) was included in the 1984 SIGGRAPH electronic theatre and reflected one of his primary philosophies, that harmony not only exists in music, but in visual imagery and life in general. Whitney passed away in 1995.

Source of images: Animation World Magazine article by William Moritz on John Whitney, 1997

Movie 2.2 – John Whitney Animation Flipbook
http://www.youtube.com/watch?v=_cmrTxtlgLA?

Movie 2.3 – Excerpt from "Computers: Challenging Man's Supremacy" (1976)
https://www.youtube.com/watch?v=5eMSPtm6u5Y

Movie 2.4 – Interview from "The Screening Room" WCVB-5 Boston
https://www.youtube.com/watch?v=BaW4DTKNflA

Movie 2.5 – Interview with John Whitney before his death
https://www.youtube.com/watch?v=pGH5aCYtjeE

Movie 2.6 – Catalog (1961)
https://www.youtube.com/watch?v=TbV7loKp69s

Movie 2.7 – Arabesque (1975)

https://www.youtube.com/watch?v=sQrq7S0dP54

Movie 2.8 – Lapis James Whitney 1966

http://www.youtube.com/watch?v=kzniaKxMr2g?

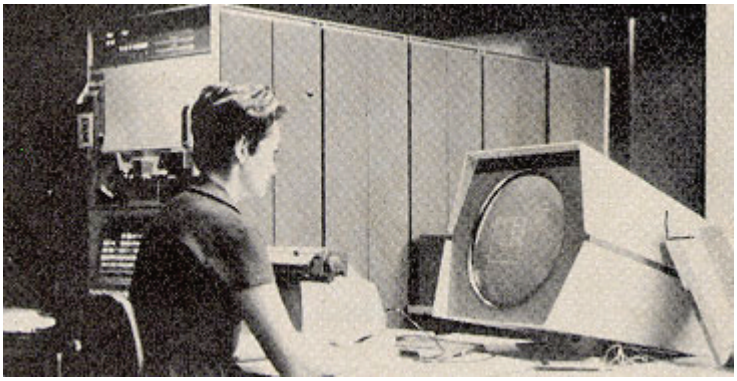
Movie 2.9 – Permutations (1966)
http://www.youtube.com/watch?v=BzB31mD4NmA?

Movie 2.10 – Matrix III (1972)
http://www.youtube.com/watch?v=ZrKgyY5aDvA

2.3 MIT's Lincoln Labs



Continuing the development of the digital computer, the TX-2 (1959) computer at MIT's Lincoln Laboratory was key in the evolution of interactive computer graphics. The Air Force paid Lincoln Laboratory to build TX-0, and later TX-2 as demonstrations that transistors, themselves relatively new, could be the basis of major computing systems. (Digital Equipment Company (DEC) formed around the people that built these machines. DEC's PDP-1 and PDP-6 computers commercialized the TX-0 and TX-2 designs.)



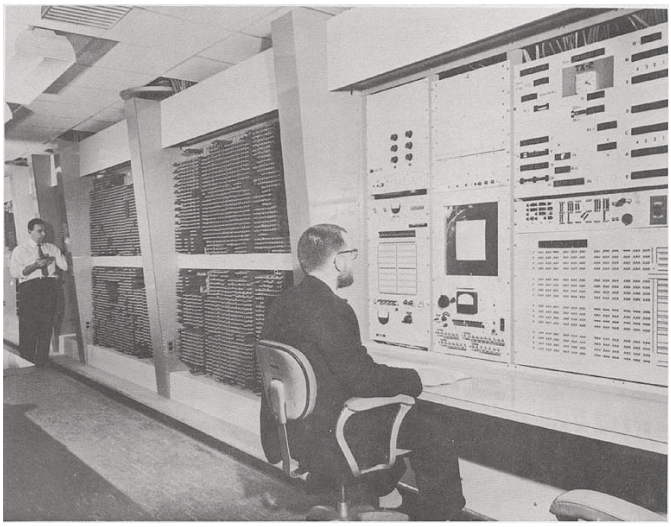
User at the console of the Digital Equipment Co. PDP-1 computer. (Source: Digital Equipment Corp.)

TX-2 was a giant machine by the standards of the day, in part because it had 320 kilobytes of fast memory, about twice the capacity of the biggest commercial machines. It had magnetic tape storage, an on-line typewriter, the first Xerox printer, paper tape for program input, and most important for the graphics industry, a nine inch CRT. The display, a light pen, and a bank of switches were the interface on which the first interactive computer graphics system was based.



Interacting with Sketchpad

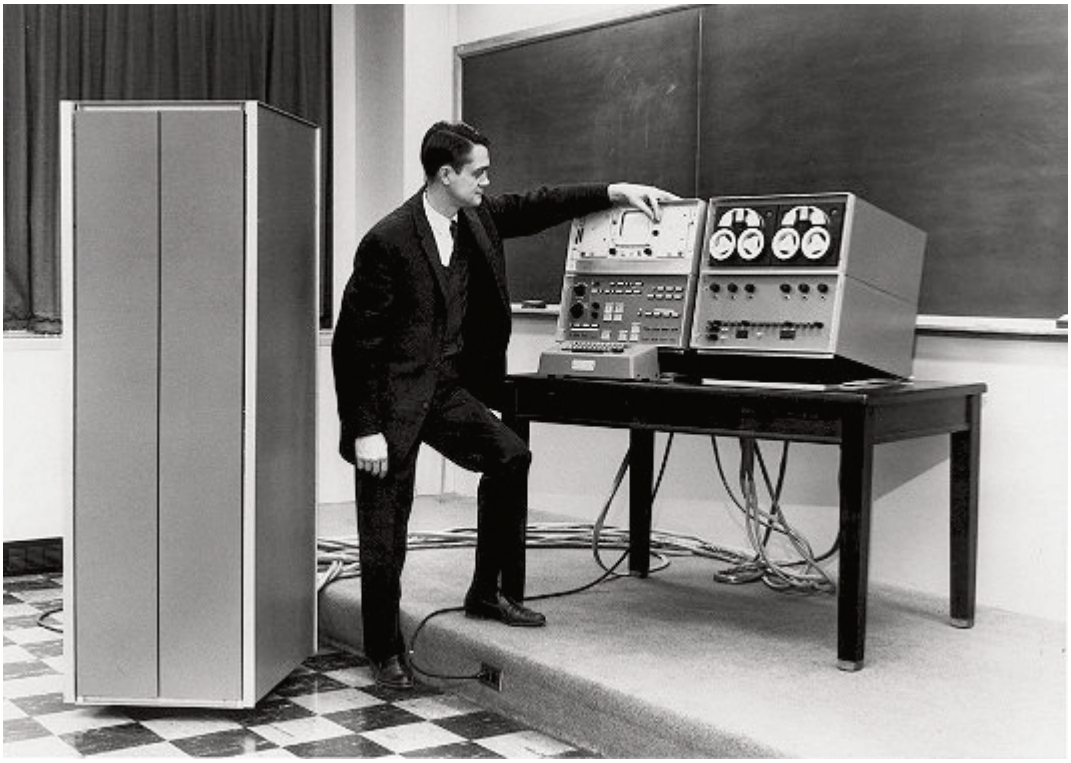
The purpose of the TX-2 was to investigate the use of Surface Barrier transistors for digital circuits. Prior to this computers were made with vacuum tubes, and it was thought that transistors would increase the reliability of these computers. Programs were written on paper tape, and fed into the TX-2 by the programmer. In the early sixties, few computers ran "on line." Instead, most computers ran "batches" of jobs submitted by users to the computer operators who scheduled the jobs to keep the computer fully occupied. Turn around time for each job was usually an hour or more, and often overnight.



TX-2 Computer (Source: Ballistics Research Laboratory Report 1115, March 1961)

Wes Clark, the man who designed the TX-2, integrated a number of man-machine interfaces that were just waiting for the right person to show up to use them in order to make a computer that was "on-line". His computer, the LINC, is considered the first minicomputer and a forerunner to the personal computer. Originally named the "Linc", suggesting the project's origins at the Lincoln Laboratory, it was renamed LINC after the project moved from the Lincoln Laboratory.

When selecting a PhD thesis topic, an MIT student named Ivan Sutherland (Chapter 3) looked at the simple cathode ray tube and light pen on the TX-2's console and thought one should be able to draw on the computer. Thus was born *Sketchpad*, and with it, interactive computer graphics.

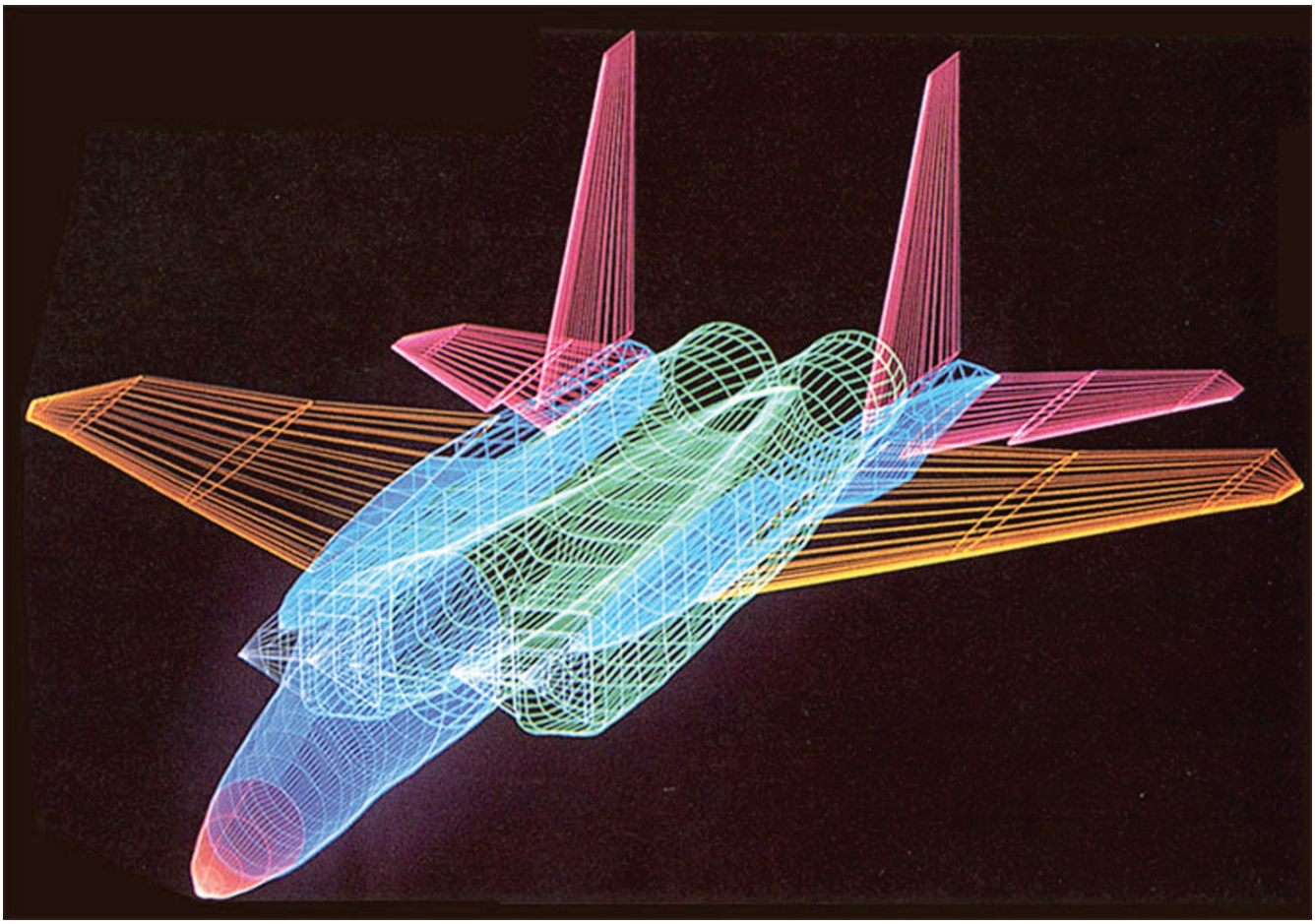


Wes Clark with the LINC computer (Source: Computer History Museum) *http://www.computerhistory.org/revolution/minicomputers/11/334*

Chapter 3: The computer graphics industry evolves

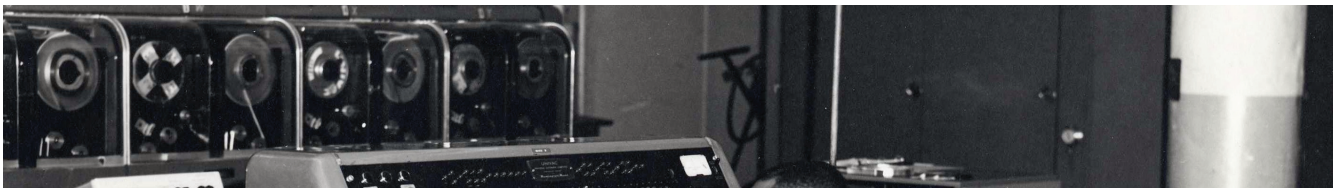
The computer graphics industry evolves

The early research and development efforts associated with the military and government sponsored invention and development of the computer, and the desire to visually represent data that was generated or stored on these computers, quickly led to the establishment of private sector companies and the beginning of the computer graphics industry.



Aircraft design from screen of Evans and Sutherland graphics workstation

3.1 Work continues at MIT



As mentioned in the previous chapter, activities at the Massachusetts Institute of Technology helped shape the early computer and computer graphics industries. Development at MIT took place in several different laboratories, including the Lincoln Labs, Electronics System Laboratory, the Center for Advanced Visual Studies, the Architecture Machine Group and the Media Lab. As mentioned in Chapter 1, Jay Forrester of the Servomechanisms Lab was chosen by Gordon Brown to develop the Whirlwind computer in the mid-40s. The Whirlwind and Forrester were moved to the Digital Computer Lab and started focusing on using the computer for graphics displays, for air traffic control and gunfire control, and became part of the government's SAGE (Semi-Automatic Ground Environment) program.

Ivan Sutherland and Sketchpad

Ivan Sutherland, acknowledged by many to be the "grandfather" of interactive computer graphics and graphical user interfaces, worked on his PhD in Electrical Engineering in the Lincoln Labs on their TX-2 computer. Sutherland learned to program in high school using a small relay computer called SIMON[1].

1. A 1950 fact sheet from Columbia University called SIMON "a very simple model, mechanical brain -- the smallest complete mechanical brain in existence." This fact sheet can be found at http://www.blinkenlights.com/classiccmp/berkeley/simonfaq.html



SIMON was a relay-based computer with six words of two bit memory. Its 12 bits of memory permitted SIMON to add up to 15. Sutherland's first big computer program was to make SIMON divide. To make division possible, he added a conditional stop to SIMON's instruction set. This program was a great

accomplishment, it was the longest program ever written for SIMON, a total of eight pages of paper tape.

This was the beginning of a distinguished career in computers, graphics, and integrated circuit design. He earned his B.S. in Electrical Engineering at Carnegie Institute of Technology (now Carnegie Mellon University) on a full scholarship. He received an M.S. from Cal Tech, and then enrolled at MIT to work on his Ph.D. His dissertation centered around an interactive computer drawing program that he called Sketchpad, which was published in 1963. His contributions moved graphics from a military laboratory tool to the world of engineering and design. Sutherland made a movie of the interactive use of ***Sketchpad***, which became somewhat of a cult film. It is widely acknowledged that every major computer graphics research lab in the country had a copy of the film, and researchers and students still refer to it over and over, as it influenced their developmental work so significantly.

Movie 3.1 *Alan Kay discusses Sketchpad*
https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/alankay-on-sketchpad-1987.m4v

Excerpted from a 1987 distinguished lecture series by computer interface pioneer Alan Kay, titled "Doing with Images Makes Symbols: Communicating with Computers"

Source: http://www.archive.org/details/AlanKeyD1987

Sutherland's software, described in a 1963 paper, *Sketchpad: A Man-machine Graphical Communications System*, used the light pen to create engineering drawings directly on the CRT. Highly precise drawings could be created, manipulated, duplicated, and stored. The software provided a scale of 2000:1, offering large areas of drawing space. Sketchpad pioneered the concepts of graphical computing, including memory structures to store objects, rubber-banding of lines, the ability to zoom in and out on the display, and the ability to make perfect lines, corners, and joints. This was the first **GUI (Graphical User Interface)** long before the term was coined.





Using Ivan Sutherland's Sketchpad on TX-2

The following text is from a citation for Dr. Sutherland when he won the Franklin Institute Certificate of Merit (1996):

At a time when cathode ray tube monitors were themselves a novelty, Dr. Ivan Sutherland's 1963 software-hardware combination, Sketchpad, enabled users to draw points, line segments and circular arcs on a cathode ray tube with a light pen. In addition Sketchpad users could assign constraints to whatever they drew and specify relationships among the segments and arcs. The diameter of arcs could be specified, lines could be drawn horizontally or vertically, and figures could be built up from combinations of elements and shapes. Figures could be copied, moved, rotated, or resized and their constraints were preserved. Sketchpad also included the first window-drawing program and clipping algorithm which made possible the capability of zooming in on objects while preventing the display of parts of the object whose coordinates fall outside the window.

The development of the Graphical User Interface, which is ubiquitous today, has revolutionized the world of computing, bringing to large numbers of discretionary uses the power and utility of the desk top computer. Several of the ideas first demonstrated in Sketchpad are now part of the computing environments used by millions in scientific research, in business applications, and for recreation. These ideas include:

1. *the concept of the internal hierarchic structure of a computer-represented picture and*
2. *the definition of that picture in terms of sub-pictures;*
3. *the concept of a master picture and of picture instances which are transformed versions of the master;*
4. *the concept of the constraint as a method of specifying details of the geometry of the picture;*
5. *the ability to display and manipulate iconic representations of constraints;*
6. *the ability to copy as well as instance both pictures and constraints;*
7. *some elegant techniques for picture construction using a light pen;*
8. *the separation of the coordinate system in which a picture is defined from that on which it is displayed; and*
9. *recursive operations such as "move" and "delete" applied to hierarchically defined pictures.*

The implications of some of these innovations (e.g., constraints) are still being explored by Computer Science researchers today.

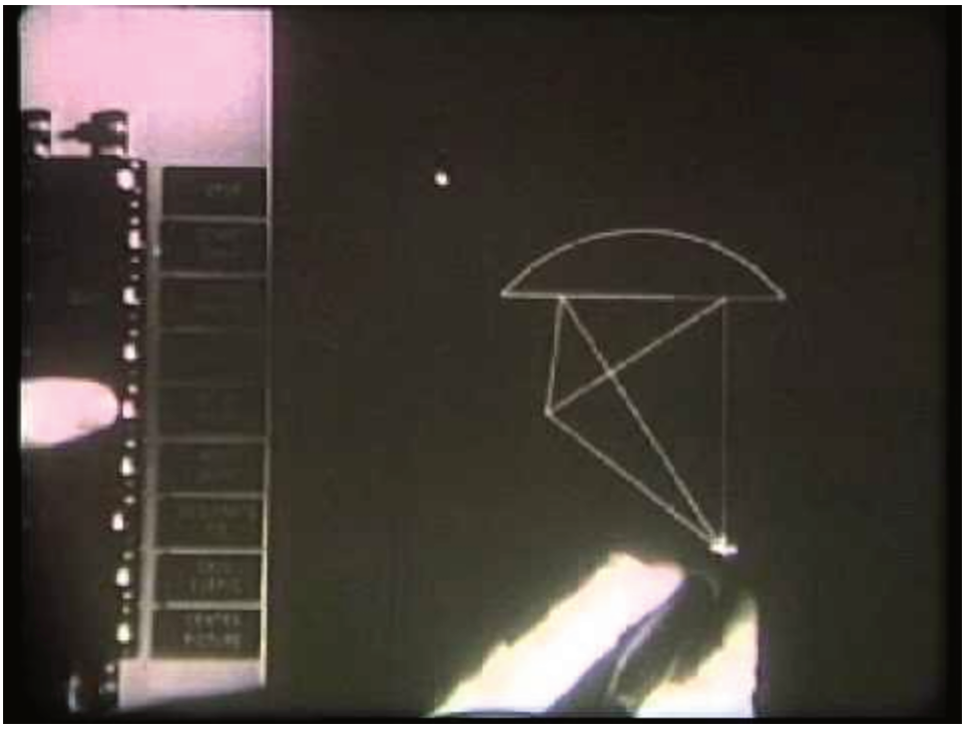
Sutherland, Ivan, *SKETCHPAD: A Man-Machine Graphical Communication System*, PhD dissertation, MIT, 1963. Reproduced as Technical Report Number 574, University of Cambridge Computer Laboratory, UCAM-CL-TR-574, ISSN 1476-2986,
http://www.cl.cam.ac.uk/

Sutherland, Ivan, *SKETCHPAD: A Man-Machine Graphical Communication System*, Proceedings of the AFIPS Spring Joint Computer Conference, Detroit, Michigan, May 21-23, 1963, pp. 329-346.
http://www.guidebookgallery.org/articles/

Toward a Machine with Interactive Skills, from *Understanding Computers: Computer Images*, Time-Life Books, 1986

More on Ivan Sutherland can be found in the chapters and sections related to the University of Utah and Evans & Sutherland Computer Company (Chapters 4 and 13, respectively.)

Movie 3.2 Sketchpad



https://www.youtube.com/watch?v=57wj8diYpgY
A copy of the first 6 1/2 minutes of the original Sketchpad demo, originally recorded on 16mm film

Center for Advanced Visual Studies

The Center for Advanced Visual Studies was established in 1967. Its founder, the artist and MIT professor Gyorgy Kepes, conceived of the Center as a fellowship program for artists.

The Center's initial mission was twofold:

- to facilitate "cooperative projects aimed at the creation of monumental scale environmental forms" and
- to support participating fellows in the development of "individual creative pursuits."

To achieve these goals, fellows worked collaboratively with each other and with the wider MIT community. Other fellows at CAVS extended this idea of artists working on projects with the assistance of engineers and scientists.

Kepes, who had taught at the New Bauhaus in Chicago prior to joining the faculty of MIT's School of Architecture and Planning in 1946, strongly believed in the social role of the artist. With the founding of the Center he sought to bring about the "absorption of the new technology as an artistic medium; the interaction of artists, scientists, engineers, and industry; the raising of the scale of work to the scale of the urban setting; media geared to all sensory modalities; incorporation of natural processes, such as cloud play, water flow, and the cyclical variations of light and weather; [and] acceptance of the participation of 'spectators' in such a way that art becomes a confluence."

According to the MIT CAVS website,

> The CAVS was established by Professor Kepes, who emphasized the responsibilities of artists in building bridges between individuals and their environment, between individuals in groups, and between each of us and our inner lives.

MIT Media Laboratory

The Media Laboratory was formed in 1980 by Nicholas Negroponte and Jerome Wiesner, growing out of the Architecture Machine Group, and building on the seminal work of faculty members such as Marvin Minsky in cognition, Seymour Papert in learning, Barry Vercoe in music, Muriel Cooper in graphic design, Andrew Lippman in video, and Stephen Benton in holography. The Media Lab conducted advanced research into a broad range of information technologies including digital television, holographic imaging, computer music, computer vision, electronic publishing, artificial intelligence, human/machine interface design, and education-related technologies. Its charter was to invent and creatively exploit new media for human well-being and individual satisfaction without regard to present-day constraints. They employed supercomputers and extraordinary input/output devices "to experiment today with notions that will be commonplace tomorrow." The not-so-hidden agenda was to drive technological inventions and break engineering deadlocks with new perspectives and demanding applications.
http://www.media.mit.edu/about/index.html

3.2 TX-2 and DEC



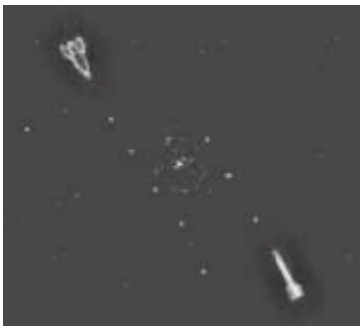
Another MIT engineer, **Ken Olsen**, was working at Lincoln Labs on the TX-2 project. In 1957 Olsen founded the Digital Equipment Corporation (DEC). He shepherded the transition of the TX-2 technology into a commercial environment, and in 1961 started construction of DEC's first computer, the PDP-1. The PDP-1 was considered a milestone in the computer era, because it was the world's first commercial interactive computer. It was used by its purchasers to pioneer timesharing systems, making it possible to have access to much more (affordable) computing power than ever before.



DEC PDP-1

In 1961 a young computer programmer from MIT, Steve Russell led a team that created the first computer game. It took the team about 200 man-hours to write the first version of ***Spacewar!*** (or *Spacewar*). They wrote *Spacewar* on a PDP-1 which was a donation to MIT from DEC, who hoped MIT's think tank would be able to do something remarkable with their product.

The PDP-1's **operating system** was the first to allow multiple users to share the computer simultaneously. This was perfect for playing *Spacewar*, which was a two-player game involving warring spaceships firing photon torpedoes. Each player could maneuver a spaceship and score by firing missiles at his opponent while avoiding the gravitational pull of the sun. Russell transferred to Stanford University, where he introduced computer game programming and *Spacewar* to an engineering student named Nolan Bushnell, who went on to write the first coin-operated computer arcade game and start Atari Computers.



Screenshot from Spacewar!

> "We had this brand new PDP-1," Steve Russell recalls. "It was the first minicomputer, ridiculously inexpensive for its time. And it was just sitting there. It had a console typewriter that worked right, which was rare, and a paper tape reader and a cathode ray tube display. Somebody had built some little pattern-generating programs which made interesting patterns like a kaleidoscope. Not a very good demonstration. Here was this display that could do all sorts of good things! So we started talking about it, figuring what would be interesting displays. We decided that probably you could make a two-dimensional maneuvering sort of thing, and decided that naturally the obvious thing to do was spaceships."
> *From S P A C E W A R – Fanatic Life and Symbolic Death Among the Computer Bums, by Stewart Brand. Rolling Stone Magazine, 12/7/1972*

Through the 1960s DEC produced a series of machines aimed at a price/performance point below IBM 's 18-bit word, core memory mainframe machines. In 1964 they introduced the PDP-8. It was a smaller 12-bit word machine that sold for about $16,000. The PDP-8 is generally regarded as the first minicomputer. It was important historically because their low cost and portability made it the first computer that could be purchased by end users as an alternative to using a larger system in a data center. Many small computer graphics labs could now have a dedicated computer on which to experiment with new software and hardware.



DEC PDP-9

Arguably the most important computer in the PDP series was the PDP-11, which switched to a 16-bit word once everyone in the computer industry started using ASCII. PDP-11 machines were introduced in the market essentially as upscale PDP-8s, but as improvements to integrated circuits continued, they eventually were packaged in cases no larger than a modern PC . Their larger PDP-10 cousins, which used a 36-bit architecture, were aimed at data-processing centers instead, eventually being sold as the DECsystem10 (or PDP-10) and DECsystem20.

While the PDP-11 systems supported several operating systems, including DEC's RSTS system, their most important role was to run Bell Labs' new UNIX operating system that was being made available to educational institutions.

The PDP-11 had a 64K address space. Most models had a **paged architecture** and memory protection features to allow timesharing, and could support split I&D architectures for an effective address size of 128K.
http://www.wikipedia.org/wiki/PDP-11

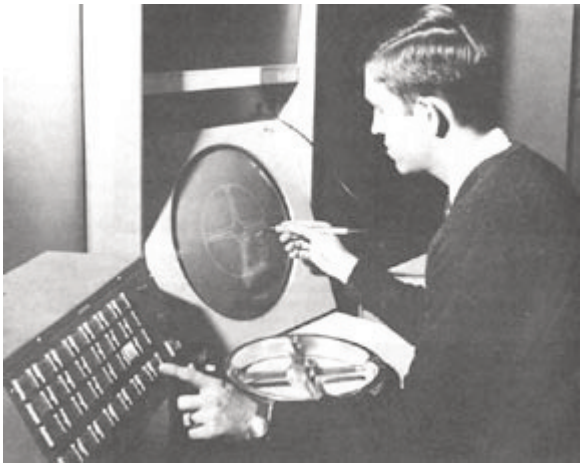


DEC PDP-11/45

In 1976 DEC decided to move to an entirely new 32-bit platform, which they referred to as the super-mini. They released this as the VAX 11/780 in 1978, and immediately took over the vast majority of the minicomputer market. Desperate attempts by competitors such as Data General (which had been formed in 1968 by a former DEC engineer who had worked on a 16-bit design that DEC had rejected) to win back market share failed, due not only to DEC's successes, but the emergence of the microcomputer and workstation into the lower-end of the minicomputer market. In 1983 , DEC cancelled their "Jupiter" project, which had been intended to build a successor to the PDP-10, and instead focused on promoting the VAX as their flagship model.

The VAX series had an instruction set that is rich even by today's standards. In addition to the paging and memory protection features of the PDP series, the VAX supported **virtual memory**.
http://williambader.com/museum/vax/vaxhistory.html

DEC was also an important contributor to the graphics display and terminal market. Their products were influenced by work in the Electronic Systems Laboratory (ESL) at MIT. In 1968 they introduced the DEC 338 intelligent graphics terminal, which was a refresh display with point, vector and character drawing capability. Other devices in this class were the DEC 340, IBM 2250, and IMLAC PDS-1. In 1974 they marketed the VT-52, which incorporated the first addressable cursor in a graphics display terminal. One of their most functional terminals, the VT-100 was introduced in 1981, and operated in hundreds of computer rooms around the world.



DEC 340 display



DEC VT-52



DEC VT-100

A common object in graphics labs was the disk cartridge, such as the DEC RK05 and RL02. The RK05 had 1.25 MB, and the RL02 had approximately 2.2 MB of storage (1.1 on each side) and a 60 ms seek time.



DEC RL-02



The PDP-11 was an important contributor to the graphics industry development, as it was one of the more common computers in universities and research labs, and DEC made RSTS and Unix available to educational institutions at little or no cost. The woman in the above documentation cover is loading the PDP-11 disk cassette, and the woman below is loading the punch card reader.



Interesting notes:

- The PDP 11/45 was featured in a *Doonesbury* comic strip in 1971.
- In 1977, Ken Olsen, founder of DEC, is said to have commented about PCs “There is no reason for any individual to have a computer in his home.”

3.3 General Motors DAC

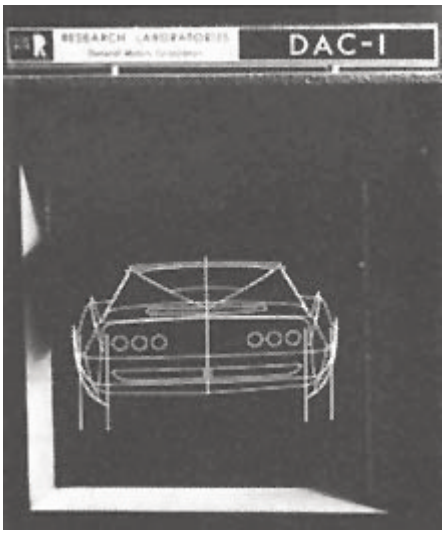


Beginning in 1959, General Motors and IBM embarked on a project to create a unified computer assisted design environment. Originally called “Digital Design”, its name was changed to DAC, for *Design Augmented by Computer*. It was formally disclosed at the 1964 Fall Joint Computer Conference. Called **DAC-1**, the first system was built by IBM using specifications provided by a team of engineers from General Motors, including Fred Krull and Dr. Patrick Hanratty, who later founded the **CADD** company MCS. The display system, sometimes considered as the first **CAD** system, introduced transformations on geometric objects for display, including rotation and zoom, and a no-display (later called “**clipping**“) function (see automobile image at the right). It used a light pencil, instead of the commonly used light gun or **light pen**. This device read coordinate voltages from a conductive transparent sheet that was positioned over the IBM Alpine display head.



DAC-1 (Source: http://www.computerhistory.org/timeline/?category=gg)

The Joint Computer Conference was held twice a year in Fall and Spring, and was a conference of a federation of the major computer societies, the American Federation of Information Processing Societies (AFIPS). It was held until 1973 when it was replaced by the National Computer Conference.



DAC Display

The DAC-1 display console was connected to an IBM 7094 computer. It utilized a very creative group design collaboration system, which consisted of a photo "readout" system connected to a projection device. When collaboration on the design drawing was desired, the operator could select a view which would be displayed on an auxiliary CRT film recorder, and it would be scanned and quickly processed, and could then be projected onto the screen. These components are all shown in the image of the system on the previous page. DAC-1 also could input drawings from other sources, such as traditional hand drawings, using a computer controlled film reader.

Movie 3.3 General Motors DAC-1 Demo

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/DAC-1demo-1.m4v

This excerpt from a DAC demonstration video shows General Motors engineers interacting with the design system.

The technology developed in the DAC project at GM resulted in the development by IBM of (among other things) the workhorse IBM 2250 graphics display, which was the interface with the IBM 1130 and 360 mainframes, and which was one of the most commonly used graphics displays of the 1960s and early 1970s. The 2250 was a vector device with 1024×1024 addressable resolution, a 12×12 inch display screen, and a .0200 inch spot size. The model 1 had a storage buffer of 8,192 bytes and a cycle time of 4 ms per byte. It had 64 non-changable characters in a built in character generator for on-screen labeling. Like many display units to follow, the 2250 had a function keyboard, an alphanumeric keyboard and a light pen. Its basic cost was around $100K. More detailed information can be obtained from an article by Arthur Appel, et al from IBM in 1968.



IBM 2250 Display

IBM developed three graphics related devices for DAC-1 — the 2250 display device, the 2280 film recorder, and the 2281 film scanner. The last two were discontinued because they were not received well in the industry.

Toward a Machine with Interactive Skills, from Understanding Computers: Computer Images, Time-Life Books, 1986

The Origin of Computer Graphics within General Motors, Fred Krull, IEEE Annals of the History of Computing, Fall 1994 (Vol. 16, No. 3); Interactive Graphics for Computer-Aided Design, by M. David Prince, Addison Wesley, 1971.

Aspects of Display Technology, Arthur Appel, IBM Systems Journal, Volume 7, Numbers 3/4, Page 176 (1968)

The complete General Motors Research Laboratories movie about DAC-1 can be viewed at? http://excelsior.biosci.ohio-state.edu/~carlson/history/moovees/GM_Design_complete.m4v

3.4 Other output devices



Other significant display devices and systems were also introduced around the same period. Many people believe that the Adage was the first stand alone computer-aided design workstation. The Adage display had the advantage of extremely high speed (for the time) display rates, allowing for the representation of moving objects and flicker free rotations. The Adage AGT-30, like the IBM 2250 became a mainstay in graphics labs around the world.



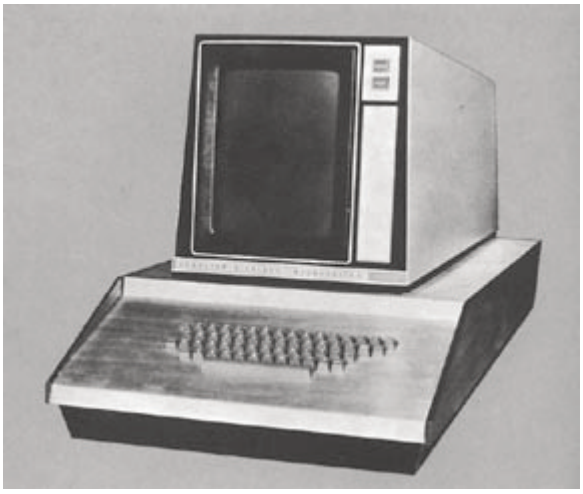
Adage Display

In a 1998 paper in the IEEE Annals of the History of Computing, Don Bissell notes that the IDIIOM CAD workstation, running the IDADS CAD software, actually preceded the Adage workstation, being introduced earlier in 1967 than Adage. Therefore, according to Bissell, "…one must respect IDIIOM's claim to historical primacy" as the first stand-alone CAD platform.

The ITEK Corporation involved personnel that got their start in the SAGE program at MIT (in particular, Thurber Moffett and Norm Taylor), and in fact was located near the Lincoln Labs facility. The ITEK project was to design optical lenses, and resulted in a system called The Electronic Drafting Machine (EDM). The EDM used a DEC PDP-1 computer from Digital Equipment Corp., a vector-refresh display and a large disk memory device used to refresh the graphic display. Input commands were done with a light pen. The EDM was developed in 1961 and was reported on in Time Magazine, March 2, 1962.

> "Technology: … to beat the language barrier between man and machine, ITEK has, in effect hitched the digital computer to the draftsman's stylus. With a photoelectric light pen, the operator can formulate engineering problem's graphically (instead of reducing them to equations) …".

Itek marketed the EDM machine and it was later sold to Control Data Corporation. It was marketed as the CDC Digigraphics System and it was heavily used in the aerospace industry at such companies as Lockheed and Martin Marietta. One of the more pricey systems, the Digigraphics system was available for approximately $500K.



Computer Displays, Inc. ARDS display



Tektronix 4010 Display

Other display devices included the storage tube display, such as the Computer Displays, Inc. ARDS and the Tektronix 4010 devices. Tektronix invented the direct view storage tube (DVST) vector graphics approach in 1965, and dominated the market for the next 15 years. They actually used their 564 storage tube oscilloscope as a computer graphics display in timeshare systems. Their 601 and 611 models introduced in 1967 were the first in their product line designed specifically for CG display. (They sold for $1050 and $2500, respectively.) The CDI ARDS (Advanced Remote Display System) actually used the Tektronix 611 6×8 storage tube, as did other systems like the Computek Display System. They were priced in the $12K range. The first commercial model from Tektronix was the 4002A, which was priced at about $9K.



Tektronix 4002A Direct View Storage Tube Display

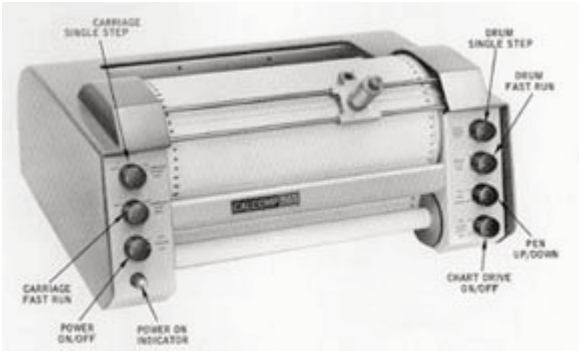
One problem with refresh vector displays is that they must continuously redraw the image on the screen, fast enough that the image doesn't "**flicker**". **Storage tube vector graphics** terminals differ from refresh vector graphics terminals in that the display maintains a "history" of what is drawn on the screen and therefore doesn't need to be refreshed. Only when the image changes does it need to be redrawn. For example, one storage tube approach uses two electron guns – one draws lines on the screen, the other bathes the entire display in electrons at a lower intensity. This second beam keeps any phosphor that has been activated continuously illuminated. However, it cannot erase anything except by clearing the entire screen. This last issue (no dynamic capability and the inability to update without erasure of the entire screen) coupled with the low light output made it not as popular for CG people as the refresh tube.

When large quantities of semi-permanent information such as maps had to be combined with dynamic or variable data, a system such as the rear projection CRT display was used. For example, the Bunker Ramo display could project color or black and white film images onto the screen of the CRT with a compensated, off-axis projector. The dynamic data was drawn using the electron gun of the CRT.



Bunker Ramo rear projection CRT

Other output devices included the **charactron** and the plotter. The charactron used a stencil mask within the CRT to efficiently draw characters on the screen. It was also used in several film recording devices, such as the Stromberg Carlson 4020 from General Dynamics. More discussion of the film recorder will take place in the sections on CGI production facilities. The first plotter developed was the CalComp 565, developed in 1958. The 565 was a high-speed drum-type XY plotter driven by step motors. Each step caused the pen to move horizontally (relative to the paper) a fixed increment (0.1 mm) in either a positive or negative direction at a rate of 250 steps per second. The drum provided the vertical movement. A solenoid permitted the pen to be lifted or lowered onto the paper. CalComp was incorporated in 1958, and introduced the 565 shortly thereafter. In 1986, CalComp became a unit of Lockheed after the company purchased Sanders Associates.



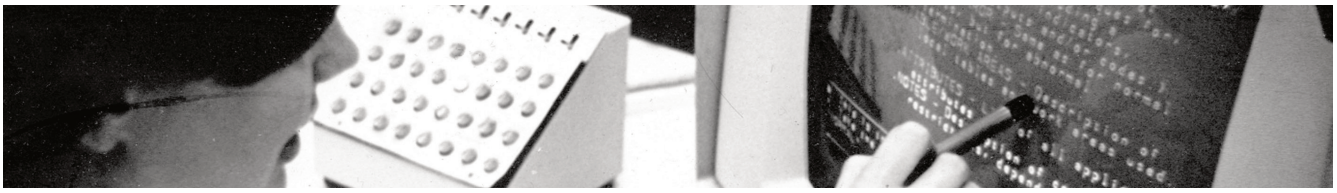
Calcomp 565 drum plotter

The **plasma panel** was a technology developed at the University of Illinois in 1964, as part of the PLATO automated teaching system. The technology used arrays of cells filled with neon gas, sandwiched between glass. Capacitors at each cell provided the driving circuitry to address and activate each cell. The plasma panel was patented in 1971 and sold to Owens-Illinois, who developed displays for use with the PLATO system. Later, Japanese and U.S. companies licensed the technology for computer graphics displays, but the technology failed to displace the CRT technology.

See "*A Colorful History of an Illinois Technology*" at *http://web.archive.org/web/20051001030137/http://www.ece.uiuc.edu/alumni/w02-03/plasma_history.html*

Machover, Carl *Computer Graphics Terminals – A Backward Look*, SJCC 1972.

3.5 Input devices



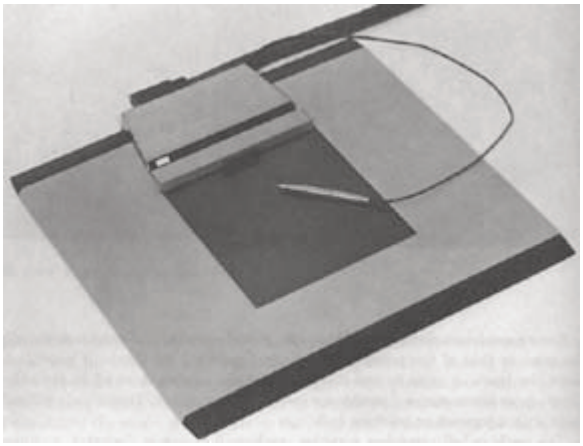
Input devices were also a very important part of the systems that were evolving during this early part of CG history. As mentioned earlier, typical input was accomplished with an alphanumeric terminal, function buttons and/or dials, and the **light pen** (or light pencil, in the case of the DAC-1 system). Also, the DAC-1 system pioneered the use of photographic input (what would later give rise to scanning technology.) The joystick was adapted to provide numerical input.



Light Pen (Source: Understanding Computers: Computer Images, Time-Life Books, 1986)

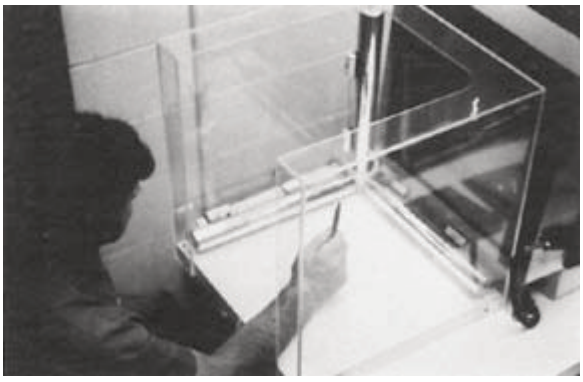
Tom Dimond patented an approach to handwriting recognition in 1957 that utilized an innovative tablet that detected the regions of interaction, giving rise to the **graphics tablet**. Sylvania introduced a tablet that operated

on analog voltage principles. One of the most innovative input approaches at the time was manifested by the Rand Tablet. It consisted of a matrix of crossed conductors. The circuitry of the tablet used switching techniques to apply pulses to the conductors in sequence, thus coding their individual locations. When a stylus was touched to the surface of the tablet, it picked up pulses capacitively from the closest of the horizontal and vertical conductors which was converted into an (x,y) coordinate value. The tablet was marketed commercially as the Grafacon tablet, and was often bundled with early DEC computers. It was priced around $18K.



RAND Tablet

A variation on the graphics tablet approach to input was the sonic pen input tablet introduced in 1970. This technology used three microphones, positioned perpendicularly in the same configuration as the cartesian coordinate axes. A stylus generated a sound, for example with a spark generator, and the position was determined by the triangulation of the distances determined by the microphones. A three dimensional (x,y,z) coordinate resulted from the input. The sonic pen device shown here being used by Charles Csuri was developed at The Ohio State University, and it is being used here to control an image on the screen of a Vector General graphics display behind it. It was also used to “trace” three dimensional objects or paths.



Chuck Csuri using OSU Sonic Pen

In 1963, **Douglas C. Englebart** was working at the Stanford Research Institute. He set up his own research lab, which he called the Augmentation Research Center. Throughout the 1960s and 1970s his lab developed an elaborate hypermedia groupware system called NLS (oNLine System). NLS facilitated the creation of digital libraries and storage and retrieval of electronic documents using hypertext. NLS used a new device to facilitate

computer interaction — the mouse. The design of the mouse included two opposing rollers set in the bottom of a block of wood. As it was rolled over a surface, the distance and the speed of the rollers inside the block could be sensed and returned to the computer to which it was attached. It could therefore control how a tracking cursor on the display moved and was positioned. A selector button on top could be pressed, defining an event that the computer could use to identify the position of the tracking cursor at the time of the event.

On December 9, 1968, Engelbart and the group of 17 researchers working with him in the Augmentation Research Center at Stanford Research Institute presented a 90-minute live public demonstration of the online system, NLS, they had been working on since 1962. The public presentation was a session in the Fall Joint Computer Conference held at the Convention Center in San Francisco. This was the public debut of the computer mouse. But the mouse was only one of many innovations demonstrated that day, including hypertext, object addressing and dynamic file linking, as well as shared-screen collaboration involving two persons at different sites communicating over a network with audio and video interface. This demonstration has become known as "the mother of all demos" at the Joint Computer Conference. The entire 90 minute demo, in 35 sections (Section 12 of the demo describes the mouse), is online at http://sloan.stanford.edu/mousesite/1968Demo.html



Englebart mouse prototype

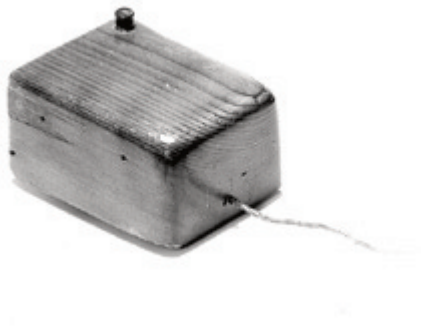
http://www.computerhistory.org/revolution/input-output/14/intro/1876

The following quotation from Engelbart is from an article titled The Click Heard Round The World, by Ken Jordan, in a 2004 issue of Wired Magazine.

> "The mouse we built for the [1968] show was an early prototype that had three buttons. We turned it around so the tail came out the top. We started with it going the other direction, but the cord got tangled when you moved your arm. ?I first started making notes for the mouse in '61. At the time, the popular device for pointing on the screen was a light pen, which had come out of the radar program during the war. It was the standard way to navigate, but I didn't think it was quite right. ?Two or three years later, we tested all the pointing gadgets available to see which was the best. Aside from the light pen there was the tracking ball and a slider on a pivot. I also wanted to try this mouse idea, so Bill English went off and built it. ?We set up our experiments and the mouse won in every category, even though it had never been used before. It was faster, and with it people made fewer mistakes. Five or six of us were involved in these tests, but no one can remember who started calling it a mouse. I'm surprised the name stuck. ?We also did a lot of experiments to see how many buttons the mouse should have. We tried as many as five. We settled on three. That's all we could fit. Now the three-button mouse has become standard, except for the Mac."



Engelbart's workstation, showing an early version (c1964) of the mouse



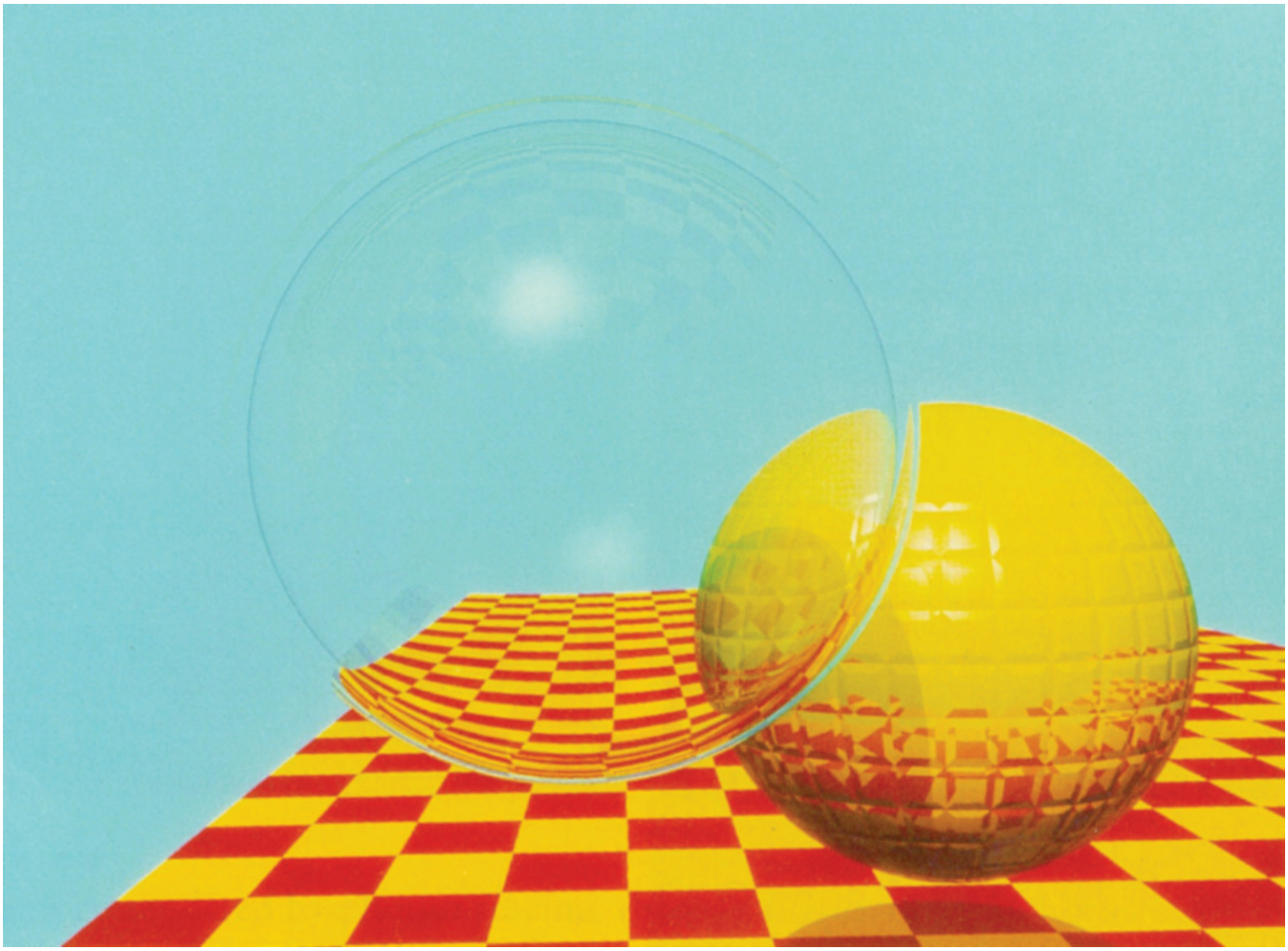
Early Engelbart Mouse

http://www.livinginternet.com

Chapter 4: Basic and applied research moves the industry

Basic and applied research moves the industry

Researchers at universities and laboratories around the world began to investigate techniques that could harness the power of the computer and its display and interaction devices to solve problems and provide capabilities that may have been outside of the reach of certain users because of the complexity of the programming process.



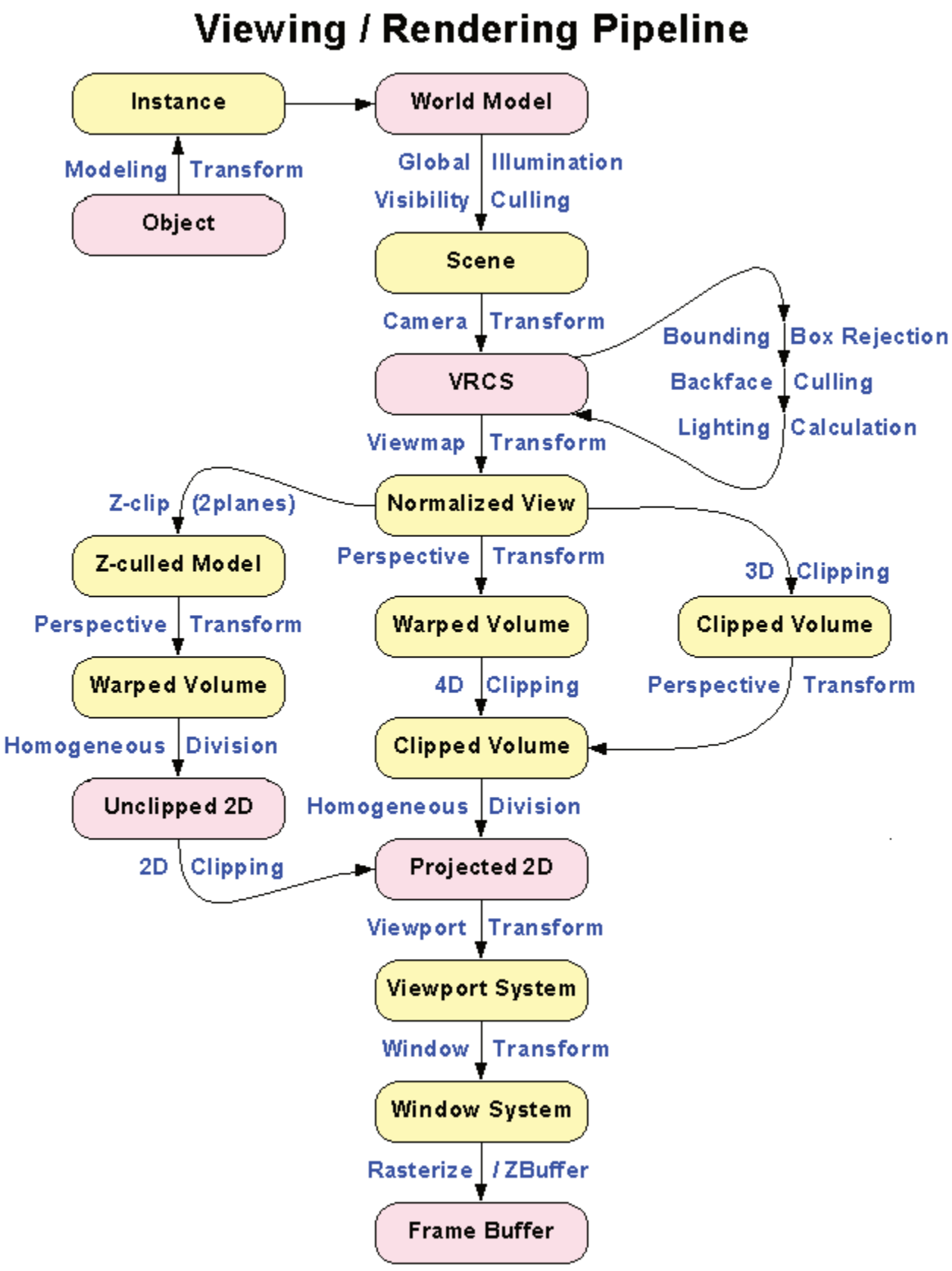
Ray-Tracing, Turner Whitted (1980)

4.1 Introduction



Much of the work in computer graphics to this point was centered around the development of solutions in the two dimensional (2D) realm. The creation of three dimensional (3D) models and images of them, while retaining accuracy of things like **foreshortening** and **perspective** and surface **rendering** were much more difficult. Some work at MIT, and companies such as IBM, Boeing, and General Motors was being done, but it took federal grants and investments to really push the evolution of the field. In particular, ARPA funding at the University of Utah and NSF funding at Ohio State, along with focused industry funding changed the direction of research.

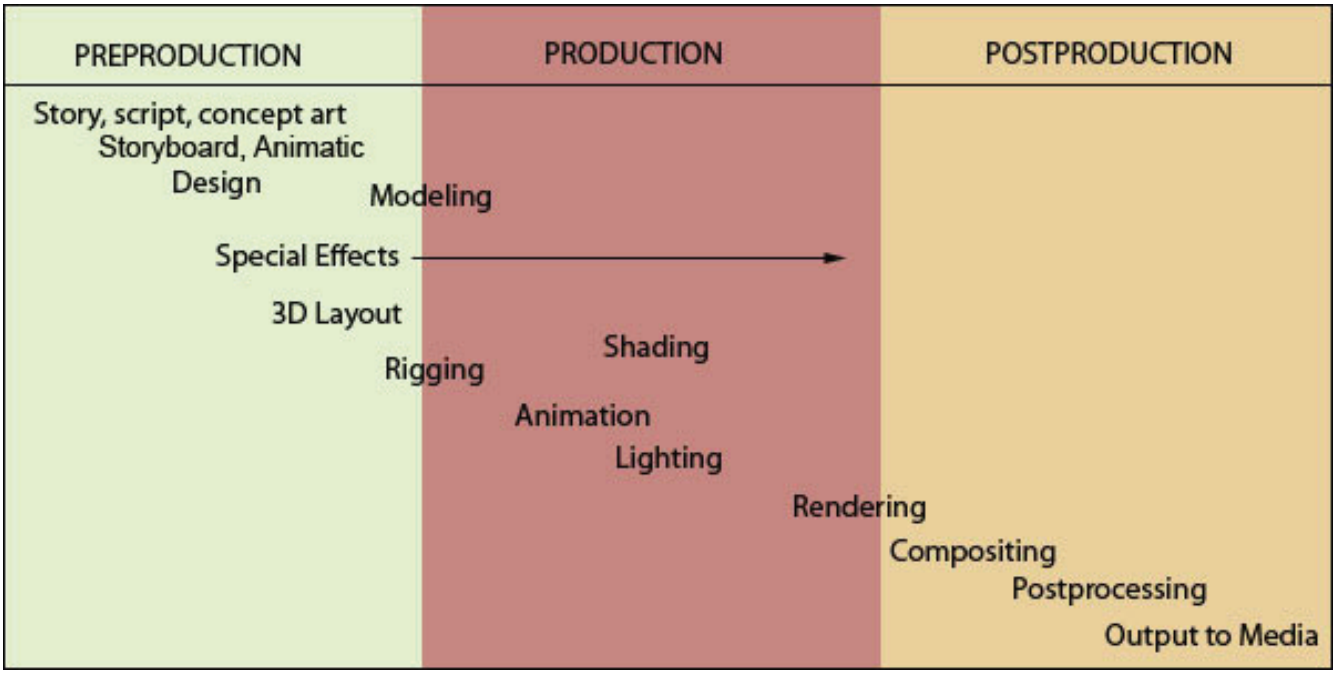
The next few chapters portray the work that was taking place in these labs, and the rapid results that came from it. To set the stage, it is valuable to look at the 3D image pipeline, which depicts the steps necessary to go from a conceptual idea with 3D geometric objects to an image depicting it displayed on the display monitor. The following chart shows the pipeline, as presented by Prof. Carlo Sequin at UC Berkeley.


Viewing / Rendering Pipeline
Instance
World Model
Modeling
Transform
Global
Illumination
Visibility
Culling
Object
Scene
Camera
Transform
Bounding
Box Rejection
VRCS
Backface
Culling
Lighting
Calculation
Viewmap
Transform
Z-clip
(2planes)
Normalized View
Z-culled Model
Perspective
Transform
3D
Clipping
Perspective
Transform
Warped Volume
Clipped Volume
Warped Volume
4D
Clipping
Perspective
Transform
Homogeneous
Division
Clipped Volume
Unclipped 2D
Homogeneous
Division
2D
Clipping
Projected 2D
Viewport
Transform
Viewport System
Window
Transform
Window System
Rasterize
/ ZBuffer
Frame Buffer

3D Pipeline

While the specific details of the pipeline are beyond the scope of this book[1], the next few chapters will look at innovations in geometric modeling, perspective representation, surface detection and representation, and the rendering process. Many of these innovations resulted in significant systems, both software and hardware, and the rise of labs and companies that resulted.

When animation is added, the pipeline expands, as shown in this chart used at Ohio State's ACCAD program, based on the definition in Isaac Kerlow's book[2]. Later chapters deal with the animation and production of realistic images and image sequences.



3D Animation Production Pipeline

One of the most difficult and time consuming components of the pipeline is the generation of complex 3D models. In 1988, John Wright started a company in Orem, Utah, called Viewpoint Datalabs, to generate these models on consignment.



Viewpoint Logo

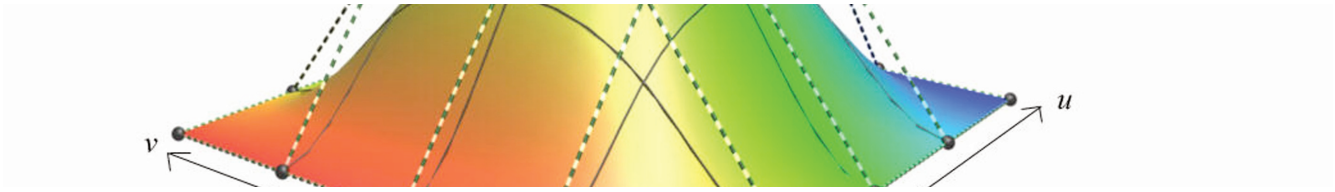
Viewpoint started as a company a that focused on accident reconstruction and courtroom visualization. Using the tools and techniques developed for that industry, they digitized models of objects including vehicles, animals, aircraft, architecture, sports, military, geography, human anatomy and more, which they delivered on DVD. The models on the disc were of four levels of detail, from simple wireframe to fully textured. Customers ranged from ad agencies, to government agencies, to game developers, to production houses and film companies.

1. For more details, see Computer Graphics: Principles and Practice, by John F. Hughes, Andries van Dam, Morgan McGuire, David F. Sklar, James D. Foley, Steven K. Feiner, and Kurt Akeley. (Revised 3rd edition of original "Foley and van Dam"), Pearson Education, 2014.
2. The Art of 3D Computer Animation and Effects / Edition 4 by Isaac V. Kerlow. Wiley, 2009.

In 1998 the company was purchased by Computer Associates International, which sold the catalogue of 3D models to Digimation in 2002. Digimation's models have been used in production by companies such as Electronic Arts for games such as Need for Speed. It's models have been featured in motion pictures including The World Is Not Enough, Pushing Tin, Star Trek: Insurrection, Independence Day, Air Force One and Godzilla.



4.2 MIT and Harvard



The late 1950s and the decade of the 1960s saw significant development in computer graphics-related computing, displays, and input and output hardware. The nature of the computer at this point in history was that it allowed programs to be written to accomplish different functions. But in the early days of computer graphics, users purchased their hardware, and the burden of developing these reusable programs, often including the development of the underlying algorithms for creating images, fell on the shoulders of the individual user.

Researchers at universities and laboratories around the world began to investigate techniques that could harness the power of the computer and its display and interaction devices to solve problems and provide capabilities that may have been outside of the reach of certain users because of the complexity of this programming process. A software industry was spawned, and turnkey systems were marketed that buffered the individual user from the computer instructions necessary to use the system to its potential.

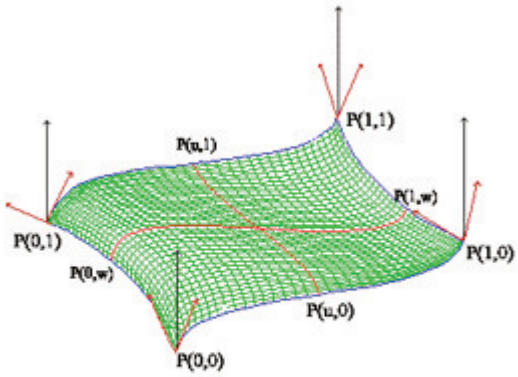
MIT

Some of the early work in computer graphics related algorithm and software development took place at the Massachusetts Institute of Technology, and at Harvard University just up the Charles River.

Tom Stockham was at Lincoln Labs on a project to use computers to process photographic material. His technique was to use a facsimile machine to "**digitize**" a photograph so that each element of the picture (what would later come to be known as the **pixel**) could be represented as a number in memory that represented a shade of gray. Once he had this image in digital form, he manipulated properties such as dynamic range and contrast, and then re-photographed the image from the screen of a CRT. Hence, what is now common in software packages such as Photoshop, that is, image processing, was developed.

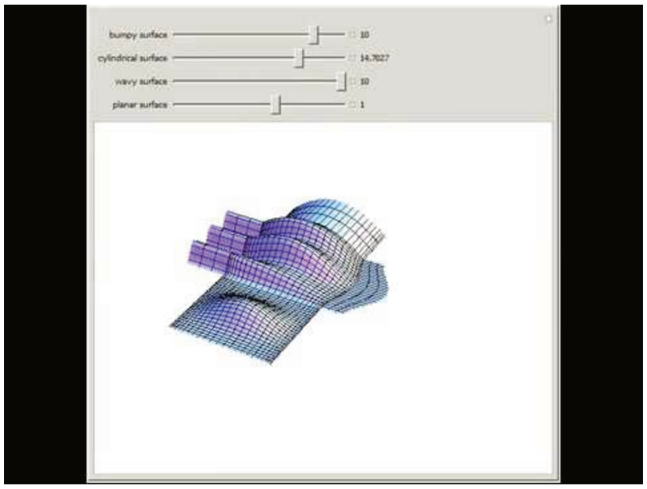
A professor in the Mechanical Engineering Department at MIT during the 1950s and 1960s, **Steven Coons**, had a vision of interactive computer graphics as a powerful design tool. During World War II, he worked on the design of aircraft surfaces, developing the mathematics to describe generalized "surface patches." At MIT's Electronic

Systems Laboratory he investigated the mathematical formulation for these patches, and in 1967 published one of the most significant contributions to the area of geometric design, a treatise which has become known as “The Little Red Book”.



Graphic representation of the Coons’ patch. The curvature on the interior is controlled by the geometry at the edges and the corners, with the depicted vectors providing the controls.

His “Coons Patch” was a formulation that presented the notation, mathematical foundation, and intuitive interpretation of an idea that would ultimately become the foundation for surface descriptions that are commonly used, such as b-spline surfaces, NURB surfaces, etc. His technique for describing a surface was to construct it out of collections of adjacent patches, which had continuity constraints that would allow surfaces to have curvature which was expected by the designer. Each patch was defined by four boundary curves, and a set of “blending functions” that defined how the interior was constructed out of interpolated values of the boundaries.



Movie 4.1 *– Generalized Coons Surface, From Wolfram’s Mathematica demonstration*

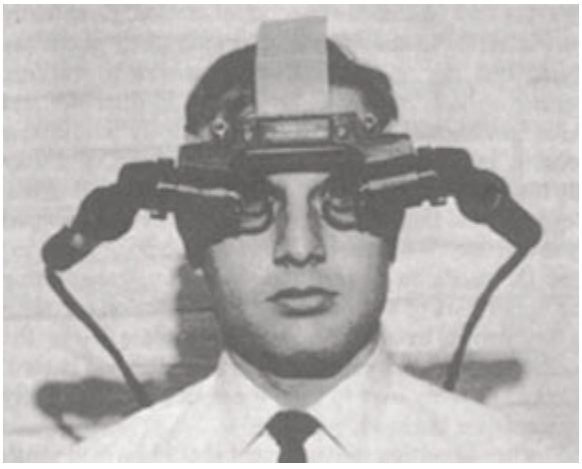
Two of Coons' students were Ivan Sutherland and Lawrence Roberts, both of whom went on to make numerous contributions to computer graphics and (in Roberts' case) to computer networks.

Lawrence Roberts wrote the first algorithm to eliminate hidden or obscured surfaces from a perspective picture. In 1965, Roberts implemented a homogeneous coordinate scheme for transformations and perspective. His solutions to these problems prompted attempts over the next decade to find faster algorithms for generating hidden surfaces, many of which were investigated at the University of Utah (Section 3 in this chapter).

Harvard University

After leaving MIT, Ivan Sutherland went briefly to ARPA, and was then recruited by Harvard. There he engaged in studies to produce pictures with dynamic perspective. The following account of these research activities at Harvard is from *FUNDING A REVOLUTION : Government Support for Computing Research*, published by the National Research Council in 1999.

> In 1966, Ivan Sutherland moved from ARPA to Harvard University as an associate professor in applied mathematics. At ARPA, Sutherland had helped implement J.C.R. Licklider's vision of human-computer interaction, and he returned to academe to pursue his own efforts to extend human capabilities. Sutherland and a student, Robert Sproull, turned the "remote reality" vision systems of the Bell Helicopter project into VR by replacing the camera with computer-generated images. The first such computer environment was no more than a wire-frame room with the cardinal directions–north, south, east, and west–initialed on the walls. The viewer could "enter" the room by way of the "west" door and turn to look out windows in the other three directions. What was then called the head-mounted display later became known as VR.
>
> Sutherland's experiments built on the network of personal and professional contacts he had developed at MIT and ARPA. Funding for Sutherland's project came from a variety of military, academic, and industry sources. The Central Intelligence Agency provided $80,000, and additional funding was provided by ARPA, the Office of Naval Research, and Bell Laboratories. Equipment was provided by Bell Helicopter. A PDP-1 computer was provided by the Air Force and an ultrasonic head-position acoustic sensor was provided by MIT Lincoln Laboratory, also under an ARPA contract.



Sutherland's Head Mounted Display

> Sutherland outlined a number of forms of interactive graphics that later became popular, including augmented reality, in which synthetic, computer-generated images are superimposed on a realistic image of a scene. He used this form of VR in attempting a practical medical application of the head-mounted display. The first published research project deploying the 3D display addressed problems of representing hemodynamic flow in models of prosthetic heart valves. The idea was to generate the results of calculations involving physical laws of fluid mechanics and a variety of numerical analysis techniques to generate a synthetic object that one could walk toward and move into or around (Greenfield et al., 1971).
>
> As Sutherland later recalled, there was clearly no chance of immediately realizing his initial vision for the head-mounted display. Still, he viewed the project as an important "attention focuser" that "defined a set of problems that motivated people for a number of years." Even though VR was impossible at the time, it provided "a reason to go forward and push the technology as hard as you could. Spin-offs from that kind of pursuit are its greatest value."
>
> Several of the original Harvard group also helped form [Evans and Sutherland], including Charles Seitz, who joined the Utah faculty in 1970 and remained until 1973, when he moved to California Institute of Technology and founded Myricom with Dan Cohen, another Harvard alumnus who contributed to the head-mounted display. The interaction between research on basic problems and development of hardware and software for military projects at Evans & Sutherland was an important feature of work at [the University of] Utah.

Sutherland's group also developed the first **clipping** algorithm, eliminating any part of a synthetic environment that was outside the "camera's" field of view, making it less computationally intensive to generate a scene on the screen.

William Newman was also at Harvard during this period. He was interested in the construction of command languages for interactive computer use. His ideas on command language programming have been very important in the evolution of the human-computer graphical interface. Newman was co-author with Robert Sproull of Carnegie Mellon of one of the most influential textbooks in the area of computer graphics, *Principles of Interactive Computer Graphics*, published by McGraw-Hill in 1973. Newman went on to continue his HCI work at Xerox PARC.

Coons, Steven A. 1967. Surfaces for Computer-aided Design of Space Forms , Project MAC Report MAC-TR-41. Massachusetts Institute of Technology, Cambridge, Mass. (*abstract*) (*full PDF*)

Sutherland, I.E., Sproull, R.F., Schumaker, R., A Characterization of Ten Hidden Surface Algorithms, ACM Computing Surveys, 6(1), 1974, pp. 1-55

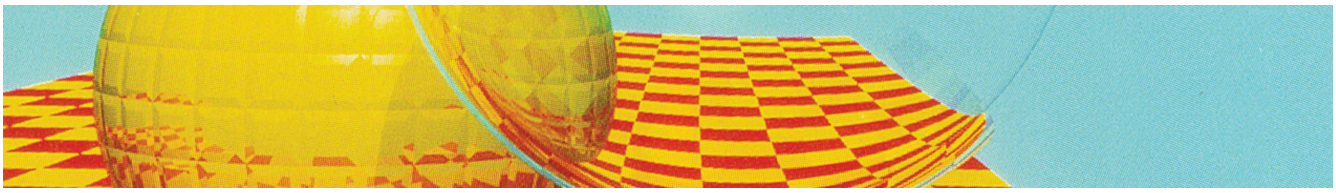
Roberts, L G., "Machine Perception of Three Dimensional Solids," MIT Lincoln Lab. Rep., TR 315, May 1963.

Roberts, Lawrence G. 1965. Homogenous Matrix Representation and Manipulation of N-Dimensional Constructs, MS-1505. MIT Lincoln Laboratory, Lexington, Mass

Retrospectives: The Early Years in Computer Graphics at MIT, Lincoln Lab and Harvard, SIGGRAPH 89 Panel Proceedings

FUNDING A REVOLUTION : Government Support for Computing Research, published by the National Research Council in 1999.

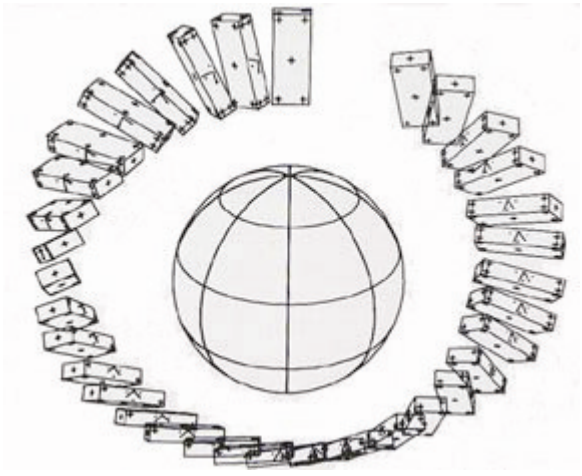
4.3 Bell Labs and Lawrence Livermore



Bell Labs

Bell Telephone Laboratories in Murray Hill, N.J. was a leading research contributor beginning with its founding in 1925, and contributed research in computer graphics, computer animation and electronic music starting in the early 1960s. Initially, researchers were interested in what the computer could be made to do in areas such as speech and communications technology, but the results of the visual work produced by the computer during this period have established people like Michael Noll and Ken Knowlton as pioneering computer artists as well as scientists. (See *The Digital Computer as a Creative Medium*, by Michael Noll, IEEE CG&A, 1967)

Physicist **Edward Zajac** produced one of the first computer generated films in history while at Bell Labs. His work was first publicized in 1963. The animation demonstrated that a satellite could be stabilized to always have a side facing the earth as it orbited. This film was titled *A two gyro gravity gradient altitude control system*. The composite shown here uses a block to represent the satellite, with each frame showing the positioning relative to the earth.



At about the same time Ken Knowlton and Leon Harmon experimented with human pattern perception and art by perfecting a technique that scanned, fragmented and reconstructed a picture using patterns of dots (such as symbols or printer characters.) Their *Reclining Nude* (a representation of dancer Deborah Hay) was submitted to one of the earliest computer art exhibitions, *The Machine as Seen at the End of the Mechanical Age*, curated by K.G. Pontus Hulten, at the Museum of Modern Art in 1968.



Cover of book "The Machine as Seen at the End of the Mechanical Age", by K.G. Pontus Hulten. The book has a printed metal cover.

Ken Knowlton developed the *Beflix* (Bell Flicks) animation system in 1963, which was used to produce dozens of artistic films by himself and artists such as Stan VanDerBeek and Lillian Schwartz.

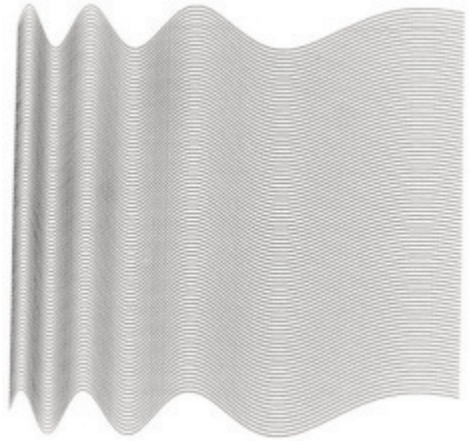
Ruth Weiss created in 1964 (published in 1966) some of the first algorithms for converting equations of surfaces to **orthographic** views on an output device. Her paper (Ref: Weiss, Ruth E., *BE VISION, a Package of IBM 7090 FORTRAN Programs to Drive Views of Combinations of Plane and Quadric Surfaces*, Journal of the ACM 13(4) April 1966, p. 194-204) was selected to be included in a 1998 compilation by SIGGRAPH of the seminal papers in computer graphics.

The artistic/scientific/educational image making efforts at Bell Labs were some of the first to show that electronic digital processing (using the IBM 7094 computer) could be coupled with electronic film recording (using the Stromberg-Carlson SC-4020 microfilm recorder) to make exciting, high resolution images. With the dozen or so films made between 1962 and 1967, and the many more films after that, they also showed that computer animation was a viable activity. Zajac's work, Frank Sinden's films (eg, *Force, Mass and Motion*) and studies by Michael Noll in the area of stereo pairs (eg, *Simulated basilar membrane motion*) were some of the earliest contributions to what is now known as scientific visualization.

Noll and other Bell Labs researchers contributed some of the earliest computer artwork in the discipline, such

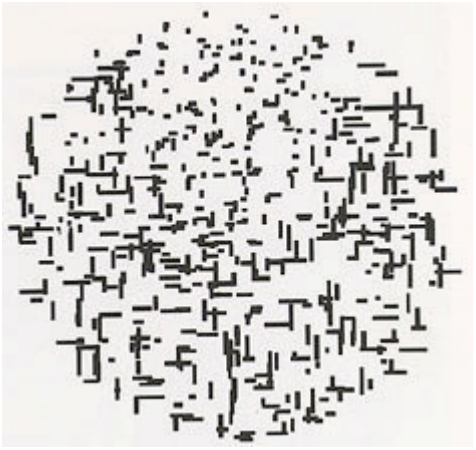
as his *Gaussian-Quadratic* (1962), to the first formal exhibition of computer art in the United States in 1965. The exhibition was called "Computer-Generated Pictures" and was located at the Howard Wise Galleries in New York. Bela Julesz, also from Bell Labs, participated in the exhibition as well, showing his work in random dot stereograms. Later that year, Noll's work from the Wise exhibition was shown at the Fall Joint Computer Conference (FJCC) of the American Federation of Information Processing Societies (AFIPS) in Las Vegas.

Some of Michael Noll's early artwork revolved around an attempt to represent existing fine art on the computer. For example, one of his early computer generated images was a rendition of "Op-artist" Bridget Riley's painting *Currents*, which Noll mimicked using a set of displaced sine waves.



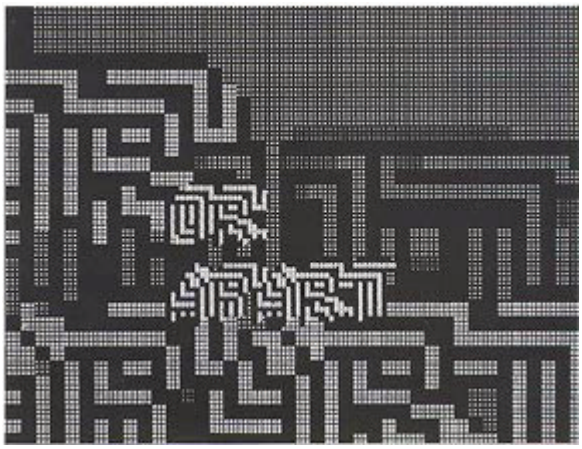
Ninety Parallel Sinusoids with Linearly Increasing Period (after Currents) – Michael Noll

He also "duplicated" Mondrian's *Composition with Lines*, using visual representations generated with "random" numbers. The circular image was presented, along with a copy of the original, to a group of scientists at Bell Labs as a perception test. (The subjects actually preferred the computer generated version, which they also tagged as the most original.)

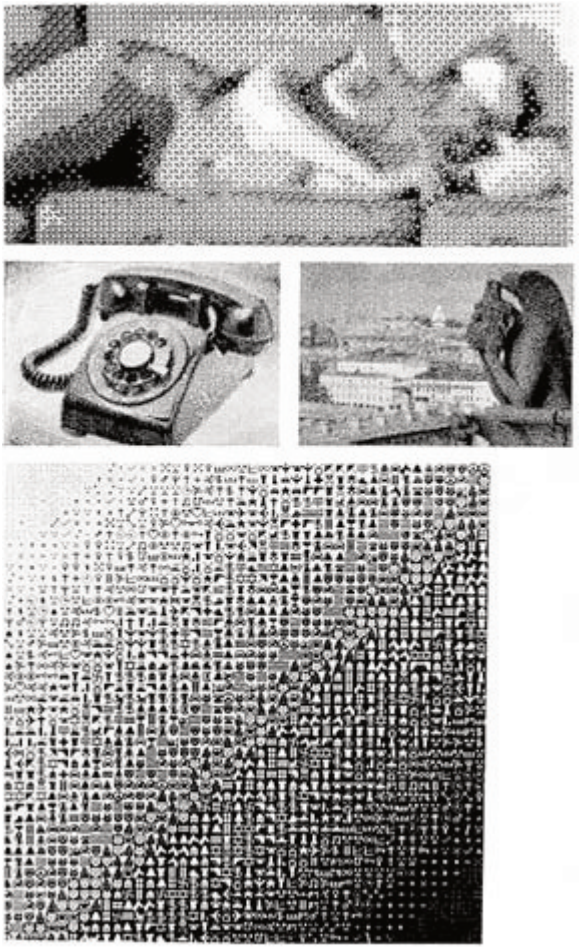


Noll's Mondrian experiment

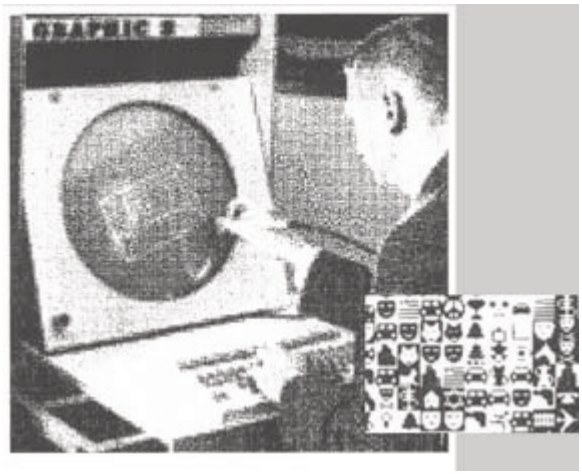
Other early "computer artists" (in addition to Noll, Knowlton, Schwartz, VanderBeek, Zajac and Harmon) working at or visiting Bell Labs were Manfred Schroeder, Laurie Spiegel, and Frank Sinden.



Vanderbeek and Schwartz



Knowlton and Harmon



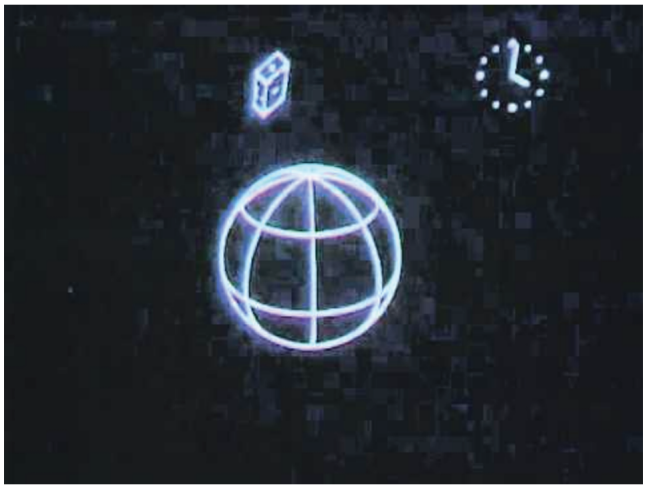
Knowlton and Harmon

Movie 4.2 Scenes from *The Artist and the Computer*

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/schwartz-1.m4v

This excerpt from The Artist and the Computer, a film by Lillian Schwartz, shows the computers and displays at Bell Labs.

Movie 4.3 Zajac Film



A two gyro gravity gradient altitude control system
https://www.youtube.com/watch?v=m8Rbl7JG4Ng

Movie 4.4 – *Incredible Machine*
Incredible Machine (1968) introduced by George Kupczak. A documentary of Bell Labs experimental advances in audiovisual communications

Movie 4.5 – *A Computer Technique for the Production of Animated Movies*
A Computer Technique for the Production of Animated Movies, Ken Knowlton (1964). The use of BEFLIX in computer animated movies

Movie 4.6 – *PoemField No. 2*
PoemField No. 2 (1966) Knowlton and VanDerBeek

Movie 4.7 – *Force, Mass and Motion*
Force, Mass and Motion (1965), Frank Sinden

Movie 4.8 – *HyperCube/4D Hypermovie*
HyperCube/4D Hypermovie (1965) Michael Noll

Computing Science Technical Report No. 99 : A History of Computing Research at Bell Laboratories (1937-1975) by Bernard D. Holbrook and W. Stanley Brown

Noll, Michael, *The Beginnings of Computer Art in the United States: A Memoir*, Leonardo V27, #1

Weiss, Ruth E. *BE VISION, a Package of IBM 7090 FORTRAN Programs to Drive Views of Combinations of Plane and Quadric Surfaces*. Journal of the ACM 13(4) April 1966, p. 194-204.

The Digital Computer as a Creative Medium, by Michael Noll, IEEE CG&A, 1967

A Computer Technique for Producing Animated Movies, by Ken Knowlton, Proc. Spring Joint Computer Conference 1964.

Early Digital Computer Art and Animation at Bell Telephones Laboratory, Inc. – Michael Noll, May 2013

Lawrence Livermore National Laboratories (LLNL)

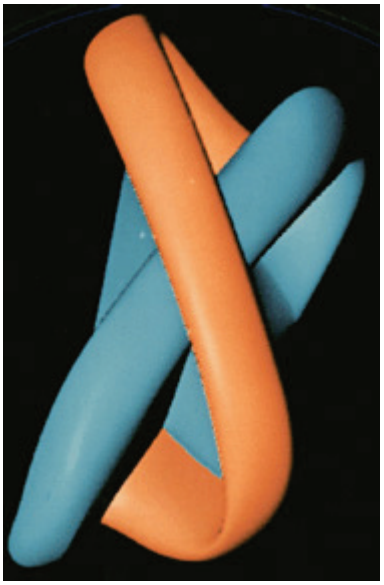
Pioneering work in software for computer graphics and animation, mostly from an applications perspective, took place at Lawrence Livermore National Laboratories beginning in the early 1950s. Their interest in this technology was related to weapons research and areas such as particle dynamics and heat/fluid flow. They contributed immensely to the evolution of “big” computing, or what is now called **supercomputing**. George Michael, who started at the Lab in 1953 has put together an interesting oral history (although its coverage is much broader than CGI at LLNL) web page devoted to the story of the lab. It can be accessed at

http://www.computer-history.info/

Steve Levine of LLNL wrote a paper for SIGGRAPH 75 describing the graphics activities there during that

period. In particular, LLNL developed a direct-to-video recording capability that could complement their film recording processes. This video preview system was cheaper than video laser recording, and provided a unique and affordable method for looking at the animation that was produced there, before committing the time necessary to put it on film.

In another part of LLNL, **Nelson Max** worked as a researcher in computer graphics and animation. Max later also became a professor at the University of California, Davis/Livermore. His research interests focused on realism in nature images, molecular graphics, computer animation, and 3D scientific visualization. He served as computer graphics director for the Fujitsu pavilions at Expo ‘85 and Expo ‘90 in Japan.



Nelson Max – frame from “Inversion of a Sphere”

Nelson received his degrees in math from Johns Hopkins, and a PhD in topology from Harvard University. He was on the faculty at Carnegie Mellon in Pittsburgh, and Case Western in Cleveland and joined LLNL in 1977. His computer generated film from that year, T*urning a Sphere Inside Out* (International Film Bureau, Chicago, 1977) is one of the classic early films in the discipline. (See *Max’s remembrances* on the making of the film from the Annals of the History of Computing, and read his *SIGGRAPH 75 paper* here).



Nelson Max molecular visualization

At LLNL he also produced a series of molecular structure animations that have served to show the role of CGI in scientific visualization and generated wide acclaim for him. The most famous of these are *DNA with Ethidium* and *Intercalation with Doxorubicin/DNA*. He was also instrumental in the success of the IMAX movie *The Magic Egg* shown at SIGGRAPH 84 in Minneapolis.



Nelson Max at the workstation, which has a frame from the movie "Carla's Island" displayed on it.

Movie 4.9 Carla's Island



https://www.youtube.com/watch?v=kO-JB1WHmRc
Historical computer generated water, by Nelson Max (1981)

Nelson Max, *My Six Years to Evert a Sphere*, IEEE Annals of the History of Computing, Vol. 20, #2, 1998.

Computer Animation of the Sphere Eversion, Nelson L. Max and William H. Clifford, Jr. Case Western Reserve University, Proceedings of SIGGRAPH 75.

Computer Animation At Lawrence Livermore Laboratory, S.R. Levine Lawrence Livermore Laboratory, Proceedings of SIGGRAPH 75.

Paul Heckbert, *Making The Magic Egg – A Personal Account*,
IEEE Computer Graphics and Applications, June 1986, pp. 3-8

Movie 4.10 – Nelson Max DNA with Ethidium (1978)
http://www.youtube.com/watch?v=TD0-2lkvfgU

Movie 4.11 – Nelson Max Intercalation of Doxorubicin with DNA (1980)
http://www.youtube.com/watch?v=pCVsJ-maSa8

4.4 University of Utah



University of Utah

The University of Utah established one of the pioneer, and certainly one of the most influential computer graphics programs in the country when they asked **David Evans** (who joined Utah in 1965) to establish a program that could advance the state of the art in this new field in 1968. The computer science department had received a large Defense Advanced Research Projects Agency (DARPA) grant ($5M/year for 3 years) which resulted in the work of many faculty and graduate students who have pushed the CGI discipline to where it is today. In the words of Robert Rivlin in his book *The Algorithmic Image: Graphic Visions of the Computer Age*, "Almost every influential person in the modern computer-graphics community either passed through the University of Utah or came into contact with it in some way."



Evans joined with Ivan Sutherland, who developed Sketchpad at MIT (see Section 4.1) and later served in a

position at the Department of Defense, to create an environment in which new problems in the discipline were proposed, and in which creative solutions were found. They later founded the Evans and Sutherland Computer Company to develop and market CAD/CAM, design, molecular modeling and flight simulators.

After the 1957 launch of the USSR Sputnik satellite in 1957, ARPA invested in programs across the country to investigate diverse areas of scientific advancement that could help the United States remain competitive in advancing technology. The funding that they provided the University of Utah, which was the fourth node on the infant ARPAnet, was to investigate how the emerging field of computer graphics could play a role in this technological competitiveness. Evans convened an "eclectic group of faculty and students" (in the words of Ed Catmull[1]) to comprise a research environment that could respond to the agency's expectations. These researchers would define and address an astounding array of research problems in a relatively short period of time.

According to a summary of University of Utah documents[2]:

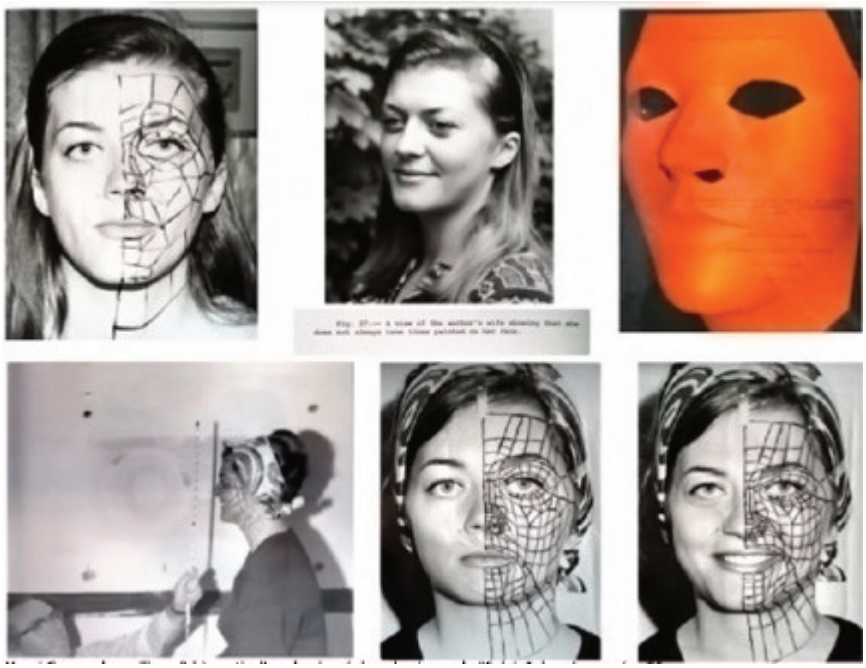
> The powerful resources at Utah were instrumental in attracting the very best faculty, students and collaborators to work with Evans on his vision. In recruiting Ivan Sutherland, Evans planned both his department and a company (Evans and Sutherland (Chapter 13.3), founded in 1968) that could develop interactive graphics workstations. Sutherland and Evans scoured the research community to attract the best talent among the skill sets required to build these systems. From MIT, they recruited engineering and signal/image processing talent, including faculty Thomas Stockham and Chuck Seitz, and Ph.D. students Donald Oestreicher and Alan L. Davis. From Ecole Polytechnique and other universities in France, they attracted the mathematical talent of students Robert Mahl, Henri Gouraud, Patrick Baudelaire, and Bui Tuong Phong.
>
> During the era of Evans and Sutherland, graduates of the Utah program made seminal contributions to rendering, shading, animation, visualization and virtual reality (notably the work of John Warnock in 1969, Henri Gouraud in 1971, Donald Vickers in 1972, Phong in 1973, Ed Catmull and Fred Parke in 1974, Henry Fuchs and Martin Newel in 1975, Frank Crow in 1976, Jim Blinn in 1978, Jim Kajiya in 1979, and many others). Additional graphics faculty hired during this time included computer artist Ron Resch (1970-1979) and Rich Riesenfeld, an expert in computer-aided geometric design (1972–present).
>
> In 1968, the equipment needed to produce an image representation was significant: a mainframe Univac performed the computations to produce the image, it sent its result to a PDP-8, which through analog output lines sent the image to a Tektronix oscilloscope to draw lines. A camera then recorded the image, without the image ever being displayed on a screen. Color images required several photos, each with a different colored filter. John Warnock, who received his Ph.D. in 1969, developed the first scientific visualizations using this approach. After Utah, Warnock moved to Evans and Sutherland, Xerox PARC, and then co-founded Adobe in 1982.
>
> The Utah Teapot is one of most iconic image in computer graphics. It was designed by Martin Newell, inspired by an actual Melitta teapot he purchased from a department store in Salt Lake City. Newell was a student of Evans, graduating in 1975, and then a member of the faculty from 1975 to 1977. Originally the teapot was sketched by hand using paper and pencil. Newell then edited bezier control points on a Tektronix storage tube. With this information he created a dataset of mathematical coordinates and a 3-D wire framing. The Utah Teapot was one of the first widely available and photogenic curved-surface 3-D models, an early

1. *Animation pioneer Ed Catmull wants the boss to get out of the way of creativity,* The Salt Lake Tribune, Apr 24 2017
2. https://en.wikipedia.org/wiki/University_of_Utah_School_of_Computing

high-quality virtual object. For this reason, it became a common benchmark model for image synthesis programs.



Utah students modeled other common objects. For his 1971 dissertation, Henri Gouraud developed Gouraud shading, using his wife Sylvie's face as a model.

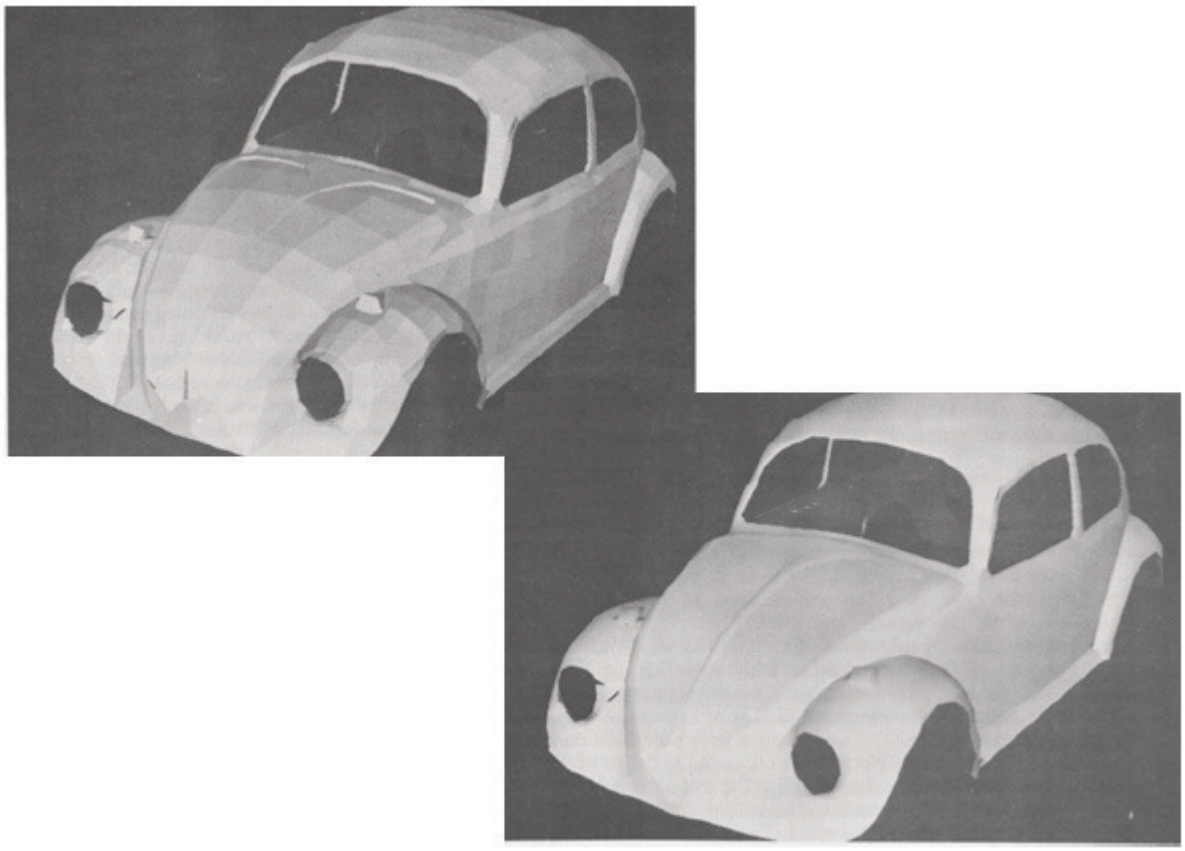


In 1972, Ivan Sutherland challenged his graphics class to choose something iconic to realistically render. The students selected the Volkswagen Beetle—as a symbol of global culture, because it was large enough to measure as a group, and because Ivan's wife, Marsha, owned one. The students painted points and lines on the surface of the Beetle to describe a set of polygons. A volleyball stanchion and joints in the pavement formed a three-dimensional reference system. The points and polygons were rendered using hardware developed by 1970 Utah Ph.D. Gary Watkins to imprint shaded images onto a direct film recorder.[3]

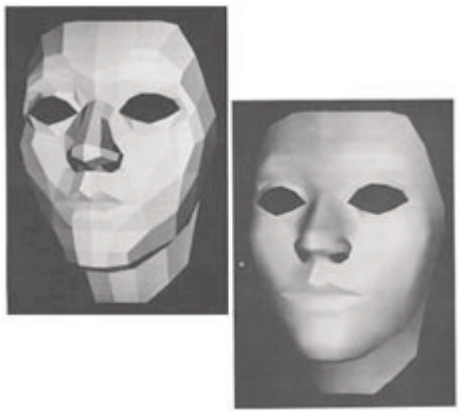
3. *Robert [McDermott] Remembers: The VW Bug* - https://www.cs.utah.edu/docs/misc/Uteapot03.pdf







Also in 1972, Ed Catmull and Fred Parke, both students of Sutherland, made a video illustrating the process of modeling Catmull's left hand and its use in animation. Catmull made a plaster mold, to which he then added points and polygons in a similar way. Catmull received his Ph.D. in 1974, and went on to help found Pixar. The video (below) has recently been added to the National Film register as one of the earliest fully rendered computer animations. Parke also used the technique for facial speech modeling.



Parke's faces

Movie 4.12 Halftone Animation (1972)

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/HandFace_1972.m4v

Halftone Animation, by Ed Catmull and Fred Parke, demonstrates shading algorithms and early lip synching efforts.



Vegreville Pysanka, constructed of 2D aluminum tiles – Geometry solved by Ron Resch and Robert McDermott

Ron Resch was on the faculty at Utah, and was contacted by a friend from Canada to help with a geometry problem that was facing a sculptor who was designing a monument to the Royal Canadian Mounted Police in 1975. The idea was to create a large (25′) egg that was reminiscent of a pysanka, or Ukranian Easter egg. Resch used early CAD design software that was being developed in the Utah lab to create a design using 524 stars and 1108 equilateral triangles out of anodized aluminum that were assembled into the 3D egg. The sculpture is located in Vegreville, Canada.

Some of the many important algorithms and theoretical results to evolve from the research in the Utah CG group include:

- *Hidden surface* (Romney, Warnock, Watkins)
- *Scan line coherence* (Watkins)

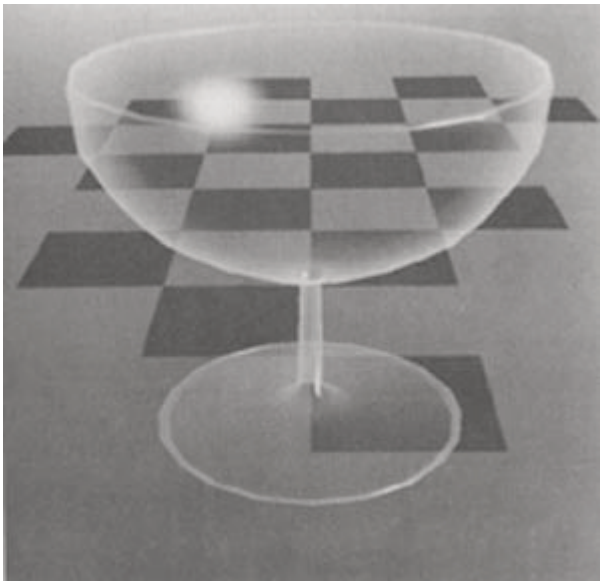
- Rendering (Crow, Blinn, Newell, Catmull, *Clark*, et al)
- *Texture mapping* (Catmull, Blinn, Newell)
- Environment mapping (*Blinn, Newell*)
- *Patch rendering* (Catmull, Clark)
- *z-buffer* (Catmull)
- *Shadows* (Crow)
- *Antialiasing* (Crow)
- *Shading* (Phong, Gouraud)
- Lighting (Phong, *Blinn*)
- Atmospheric effects (*Blinn*)
- *Blobby surfaces* (Blinn)
- *Facial animation* (Parke)
- *Procedural modeling* (Newell)
- Splines (Riesenfeld, Lyche, Cohen)
- Beta-splines (Barsky)

and many others. Many of these algorithms have resulted in the generation of significant hardware implementation, including LDS-1, the SGI Geometry Engine, the Head Mounted Display, the modern frame buffer, flight simulators, etc.





Texture maps and reflection maps from Ed Catmull's dissertation



Phong shading on transparent glass



Jim Blinn – bump mapping

One of the early "**motion capture**" systems was developed at Utah by Robert Burton in Sutherland's lab. Called the Twinklebox, the system used a collection of LEDs, which could be illuminated in rapid succession under computer control, and an elaborate scanning mechanism, consisting of a spinning disk with narrow radial slits

and lenses. The scanning discs, positioned in the corners of the room, allowed the system to create a series of one dimensional scans of the environment, including the lights. Using a mathematical process, these scans were combined to determine 3D positions for each of the lights.

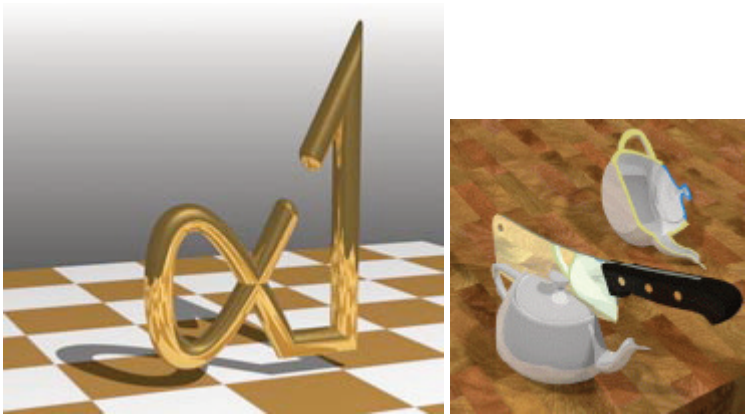
The early facilities at Utah included two PDP-10 computers, one of which used the TENEX multi-access system, while the other remained a single access computer. The head mounted display developed by Sutherland at Harvard was interfaced to the single access computer, as was the Twinklebox. A hardware implementation of the Watkins algorithm was used for display, and the LDS-1, developed by E&S was also connected to the PDP-10. This entire environment was connected to the new ARPA network.

A well known contribution of the Utah group was the Utah Raster Toolkit, developed by Spencer Thomas, Rod Bogart and John Peterson. The Utah Raster Toolkit was a set of programs for manipulating and composing raster images. The tools were based on the Unix concepts of pipes and filters, and operated on images in much the same way as the standard Unix tools operated on textual data. The Toolkit used a special **run length encoding** (RLE) format for storing images and interfacing between the various programs. This reduced the disk space requirements for picture storage and provided a standard header containing descriptive information about an image.

Individuals who were involved in the Utah program have established many leading companies in the graphics industry, including E&S, Silicon Graphics, Adobe, Ashlar, Atari, Pixel Planes, Netscape, Pixar, etc.

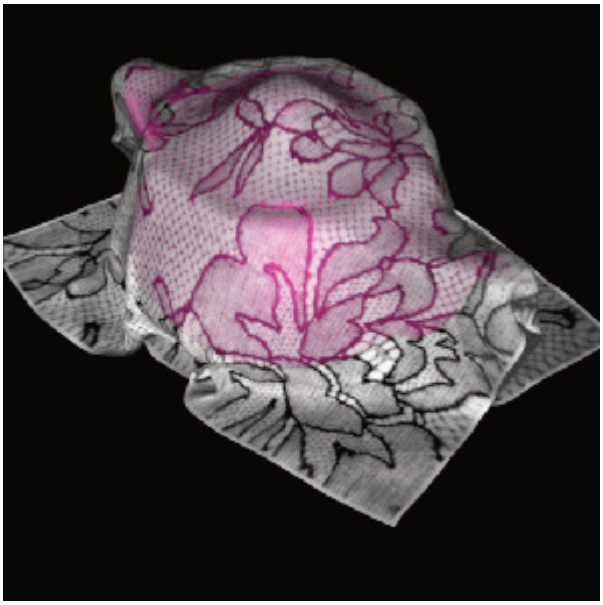
The Utah program later evolved into the *Geometric Design and Computation group* (GDC), established by Rich Riesenfeld and Elaine Cohen. The GDC was engaged in both fundamental and applied research in developing methods for representing, specifying, manipulating, and visualizing geometric models. The group had projects ranging from early conceptual design methods to innovative manufacturing processes and from detail modeling applications to large-scale assembly systems. Supporting these applications was fundamental work on surface and model representation, computational geometry, topology, differential geometry, and numerical methods.

One of the early premiere GDC efforts was the Alpha_1 modeling environment. Based on GDC project research results, the Alpha_1 system was an advanced research software base, supporting use and research in geometric modeling, high-quality graphics, curve and surface representations and algorithms, engineering design, analysis, visualization, process planning, and computer-integrated manufacturing.



Solid models in Alpha_1 were represented by trimmed B-spline (NURBS) sculptured-surface boundary representations. That is, the surfaces of a solid were represented explicitly, and linked together by shared edges.

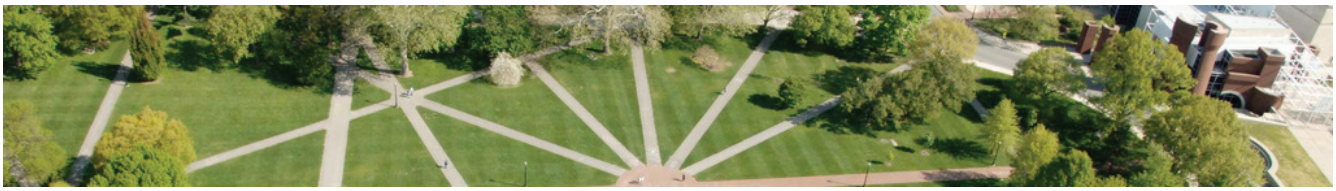
It was implemented in C++, and provided both command-language and graphical, menu-driven interfaces. Much of the heart of the geometry was based on the pioneering spline work of Riesenfeld (Syracuse University) and the subdivision work of Riesenfeld, Cohen and others.



More about Alpha_1 can be found at

http://www.cs.utah.edu/gdc/projects/alpha1/

4.5 The Ohio State University



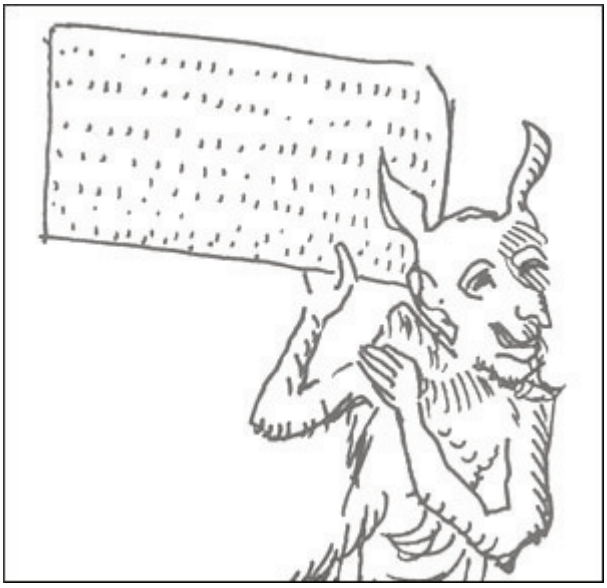
Charles Csuri, an artist at The Ohio State University, started experimenting with the application of computer graphics to art in 1963. (See *Art, Computers and Mathematics*, by **Charles Csuri** and James Shaffer, AFIPS Conference Proceedings, V33, FJCC, 1968). His efforts resulted in a prominent CG research laboratory that received funding from the National Science Foundation and other government and private agencies. The work at OSU revolved around animation languages, complex modeling environments, user-centric interfaces, human and creature motion descriptions, and other areas of interest to the discipline.



After Albrecht Dürer (1964)

Working as a painter, Csuri[1] became increasingly fascinated with the computer and its potential as an artistic tool. His early “computer” work involved the creation of an analogue device to process images, much like a pantograph traces an image. By changing the length of one or more components, the image could be redrawn in a transformed state. In a pointed commentary on the state of the technology at the time he created an image of a devil holding a punch input data card.

1. Csuri was featured in a 1995 cover article of the Smithsonian magazine, written by Paul Trachtman and titled "Charles Csuri is an 'Old Master' in a New Medium".



Devil with Punch Card (1964)

In 1967, he used a line drawing of a man, and working with a fellow faculty member (James Shaffer) from the Department of Mathematics, modified its shape using a sine curve mapping and a mainframe computer (IBM 360). Lacking an output medium for recording this primitive animation, he plotted the intermediate frames on paper using an IBM plotter to create a haunting blend of images (called Sine Curve Man).



Sine Curve Man (1967)

That same year, he continued with this experimentation on other drawings, including one of a *hummingbird* in flight. Csuri produced over 14,000 frames, which exploded the bird, scattered it about, and reconstructed it. These frames were output to 16mm film, and the resulting film Hummingbird was purchased by the Museum of Modern Art in 1968 for its permanent collection as representative of one of the first computer animated artworks.



Hummingbird (1968)

Also in 1968, Csuri was one of the featured artists at an exhibition at the Institute of Contemporary Arts in London, and his work in computer animation was featured in the catalogue titled "*Cybernetic Serendipity – the computer and the arts*," published that year by Studio International. This publication was the one of the first collections that dealt with "…the relationships between technology and creativity."



View of the Cybernetic Serendipity exhibition in 1968. Csuri's art can be seen on the black board in the center of the photo.

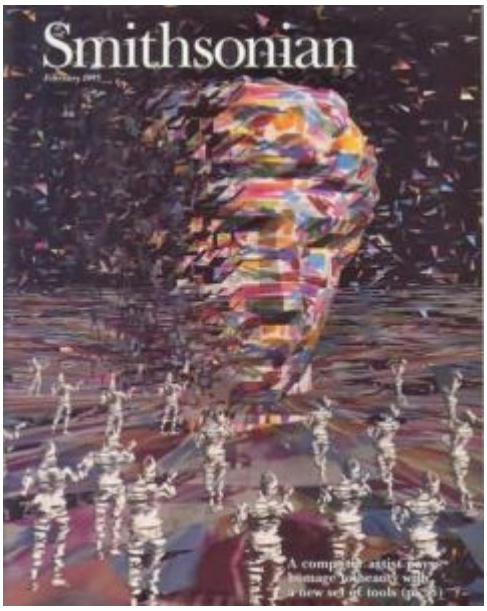


Numeric Milling (1968)

At the end of the decade, Csuri was also experimenting with many different kinds of output media, collaborating with mathematicians and scientists. One of his partners created a “tool” for defining a mathematical surface (what became known as the Fergusen patch) that Csuri then had sculpted in wood on an Engineering Department milling machine.

Csuri continued to work with graduate students and fellow faculty members from the arts and sciences for the next several years, experimenting with different approaches to instructing the computer to display and animate the various artifacts that he conceived. In 1969 he received a prestigious grant from the National Science Foundation to study the role of the computer and software for research and education in the visual arts. This was very unusual, for an artist to receive an NSF grant, and showed the level of significance of the work at OSU at the time. (In fact, an internal report done at the National Science Foundation stated that the greatest impact on the field of computer animation could in part be attributed to the work at the Computer Graphics Research Group at Ohio State.)[2]. Additional images from Csuri can be seen below in Gallery 4.1.

2. Csuri was featured in a series of prestigious retrospective exhibitions of his work. The SIGGRAPH professional graphics organization hosted an exhibition of his work titled "Beyond Boundaries, 1963-present" in 2006 in Boston. This exhibition also traveled to the Kaohsiung Museum of Fine Arts in Taiwan in 2008, to several venues in Europe, and to the Urban Arts Space in Columbus, Ohio in 2010.



Csuri, featured in Smithsonian Magazine

In 1971 he proposed a formal organization, called the Computer Graphics Research Group (CGRG) in order to realize the potential of the application of computer animation to the studies by students in the Art Department, and to have a formal cohort that could attract external research support. Members of CGRG included faculty and graduate students from Art, Industrial Design, Photography and Cinema, Computer and Information Science, and Mathematics. Grant proposals were submitted to agencies and programs both in and out of the University, and funding was provided for studies that would extend the capabilities of the evolving discipline. The group was housed in space in the OSU Research Center at 1314 Kinnear Road on the OSU campus. Equipment in the lab at this time included a 32K IBM 1130 computer interfaced to an IBM 2250 Model IV graphics display, and the FORTRAN programming language was used as the primary programming environment.

Research and development work conducted by CGRG members during this early period included hidden line and visible surface algorithms, linear interpolation, path following, data smoothing, shading and light source and reflection control, compound transformations, 2D and 3D data generation and sophisticated interaction techniques. This seminal work evolved into a general interest in dynamic systems and languages for applications in computer-controlled display and motion. In 1970, Csuri published one of the first papers related to the complex issue of animating objects in real time.



Chuck Csuri working with light pen attached to a Vector General vector graphics display



CGRG's DEC PDP-11/45 computer

Csuri was awarded his second NSF grant in 1971 for a project titled "*Software and Hardware Requirements for Real Time Film Animation*." The University provided matching equipment support, and the CGRG installed a 48K word PDP-11/45 computer and a Vector General graphics display with 3D hardware transformation capabilities in 1972. This grant supported Computer Science graduate students Tom DeFanti, who developed the animation language Graphics Symbiosis System (GRASS) in 1972, and Manfred Knemeyer, who developed the ANIMA system in 1973 for defining computer generated motion, using an integrated programming language. (Staff member Gerard Moersdorf helped write a large amount of the GRASS code.) Both of these systems were designed with traits that DeFanti, who went to the EVL at the University of Illinois, called *habitability* (ease of use by novices) and *extensibility* (the use of stored files to be interpreted by the system), and both linked to external controls like dials, buttons and joysticks in addition to command line control.

Expanding on Csuri's early work in blending of line drawing images, Mark Gillenson developed a system (WhatsIsFace) that used techniques of key frame animation to blend images to create facial drawings, a system that created a significant amount of interest in the police and investigative communities. This system was one of the first formal contributions to the technology that is now called "**morphing**".

CGRG efforts embraced a fundamental philosophy that these complex computer animation capabilities could be made available on microcomputers (eg, PDP 11/45) and could be easy to use. The group continued to receive NSF and other internal and external support for this effort, and published extensively during the early 1970s on animation and animation control as well as human-computer interfaces. The University expanded their support and funded additional equipment (another Vector General display, a computer-controlled camera system, and a communications link with the University's PDP-10 mainframe.) In 1975, Csuri contracted with John Staudhammer of *NC State* (through his company Digitech) to build a special "run-length encoding" storage and display device that allowed CGRG to move from a strictly vector display environment to raster and color graphics.

Richard Parent joined CGRG in 1974 to develop geometric modeling tools for animation (his 1977 dissertation received the "Best PhD Dissertation Award" from the National Computer Conference). During this early period, Alan Myers studied and developed **rendering** algorithms (coded in the PDP 11 assembly language) that could run efficiently in the minicomputer environment to make high quality imagery.

Ron Hackathorn worked to expand Knemeyer's Anima animation system, and Tim Van Hook brought a user perspective to the design, as well as a knowledge of real time issues.

Movie 4.13 Pong Man

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/pongman_77.m4v

Pong Man was created by Tim VanHook to demonstrate the use of Anima II to produce creature motion.

The development activities resulted in the ANIMA II animation system, which supported procedural modeling and run-length encoding algorithms, the DG modeling system for data generation, and other supporting systems and languages. The group expanded to include Rodger Wilson and Wayne Carlson, and a number of other graduate students from various departments during this period.



8-legged articulated mobile robot

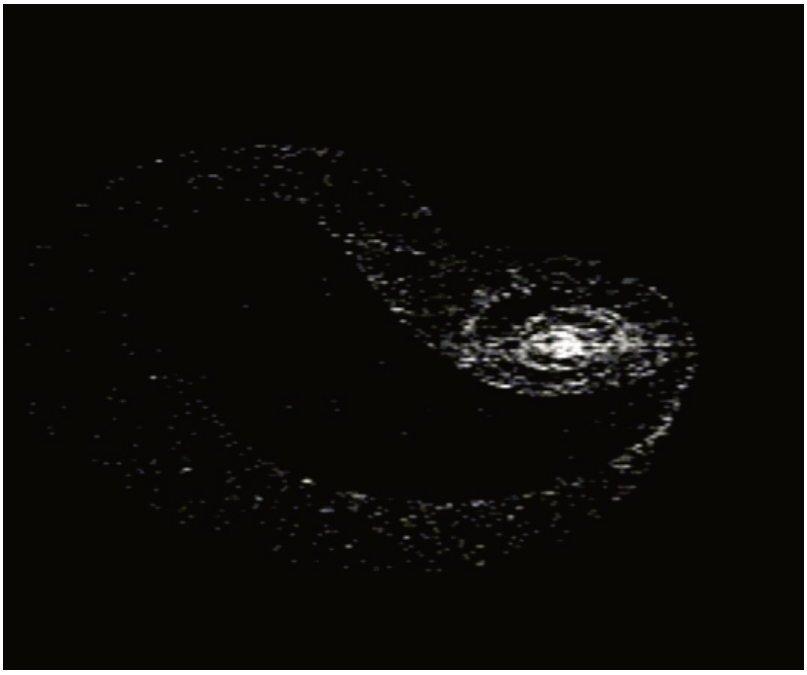
Early investigations into “creature” animation were both influenced by and supported the work of OSU Prof. Robert McGee and his 8-legged articulated mobile robot designed and built at Ohio State.

CGRG team members used the systems that were developed in the lab to generate computer animations that were shown throughout the mid to late 1970s, and published the results of their work in SIGGRAPH proceedings and other journals. The group was also featured in many popular media presentations, including television features such as PM Magazine and the national CBS Sunday Morning with Charles Osgood.



Charles Osgood, host of CBS Sunday Morning, featuring CGRG

Important work produced during this period included a visualization of interacting galaxies, which was shown on the Carl Sagan Cosmos series, by Bob Reynolds (it was updated with a complex **particle system** in 1978 by Wayne Carlson), studies of time in virtual environments, the use of CGI in visualizing statistical data, the use of animated sequences to help teach language constructs to deaf children, terrain modeling and harbor pilot training simulation, and computer art. CGRG created one of the first 3D computer generated animations used for a television station, the CBS affiliate WBNS-TV in Columbus, Ohio in 1978.



Interacting Galaxies



Frame from WBNS animation

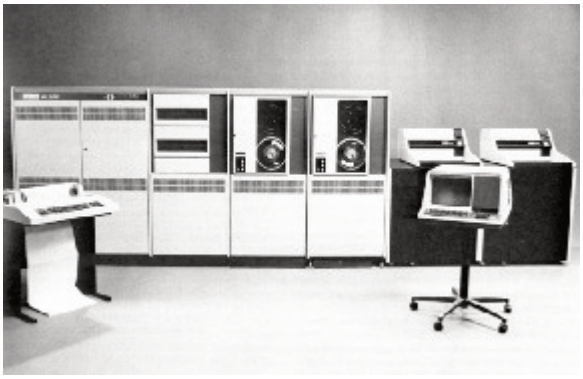
Funding for the research at CGRG was provided by the University, the National Science Foundation, the Naval Weapons Training Center, the Air Force Office of Scientific Research, and the U.S. Department of Education. Carlson and Rick Parent were also part of a consulting team to Boeing to conduct a major graphical user interface study for the Air Force ICAM (Integrated Computer Aided Manufacturing) program.

In the late 1970s, the focus of the work turned in the direction of increased complexity of modeling and animation and visual accuracy. Ron Hackathorn and Rick Parent developed the next generation animation system, called ANTSS, which was one of the first systems that combined motion specification and rendering in the same system.

As mentioned earlier, Parent received his PhD degree in 1977, which focused on a modeling system called DG, which was likened to a tool for sculpting clay in the computer environment. Parent was appointed the Associate Director of the lab after his graduation.

Wayne Carlson worked with Rodger Wilson and Bob Marshall to expand the procedural animation capabilities introduced by Martin Newell of the University of Utah, and also developed an expanded surface modeling environment that used higher order curves and surfaces, such as Bezier and b-splines, as part of his PhD research. Carlson also investigated ??points as a display primitive that could be used to efficiently compute and display "fuzzy" objects, i.e. those with no "solid" 3-D structure (eg, smoke, fire, water, etc.) He applied this research to generate an image of a smokestack, and he recalculated the interacting galaxies sequences first produced by Reynolds, increasing the geometry from several hundred geometric primitives (stars) to over 30,000 in each galaxy.

Carlson's DG2 system expanded the modeling work of Rick Parent, and was a system for modeling geometry that included points as a geometric primitive (what would later become known as **particle systems**), boolean operators on surface patches, and a unified approach to sweep operators. CGRG images from this period can be seen in Gallery 4.2 below.



DEC VAX 11/780

Frank Crow, a PhD student of Ivan Sutherland at Utah,was recruited from the University of Texas and worked with approaches to increased scene description and rendering capabilities and continued his work with shadows and antialiasing that were started at the University of Utah. At CGRG he investigated multi-processing approaches to image synthesis and other algorithmic solutions for complex images. He later went to Xerox PARC, Apple Computer, Interval Research, and then to NVIDIA.

During Crow's tenure at OSU, the PDP-11/45 was replaced with one of the earliest VAX 11/780 models on the market, and the FORTRAN and assembly language code was translated to the C language in the Unix environment.

Dave Zeltzer developed goal-directed motion description capabilities for skeletal and creature animation (the *Skeletal Animation System – SAS*). His system and the underlying theories are some of the most significant contributions to the area of autonomous legged motion description in the discipline.

Don Stredney (the Ohio Supercomputer Center) pushed the limits of the modeling systems of Carlson and Parent to develop complex anatomical models, including the skeleton"George" used by Zeltzer in his research. George became a graphics "cult" figure, and the geometric model was distributed widely throughout the field.

Mark Howard moved from Staudhammer's NC State program and designed and built a controllable 512×512 frame buffer that allowed real-time playback of animation tests. This frame buffer and later versions of the design were the mainstay of the image creation and representation capabilities at CGRG and later at Cranston/Csuri Productions.

Julian Gomez developed TWIXT, a track-based **keyframe** animation system. This system allowed for the specification of key-framed motion for independent objects that moved over the same time interval. It had real time playback, with shape morphing, and was device independent.

Other important work done during this period included films *Snoot and Muttly* by Susan Van Baerle and Doug Kingsbury, *Trash* by John Donkin, *Tuber's Two-Step* by Academy award winner Chris Wedge, *Vision Obious* by Ruedy Leeman, early character animation by Michael Girard and George Karl, and animations by Susan Amkraut, Marsha McDevitt, Thuy Tran, Kevin Reagh, Anne Seidman, Tom Hutchinson, Bill Sadler and others. CGRG images from this period can be seen in Gallery 4.3 below.

CGRG continued to advance, concurrently with the efforts at Cranston/Csuri Productions (see Chapter 6) across the lobby in the 1501 Neil Avenue building. In 1987 Tom Linehan and Chuck Csuri oversaw the conversion of the Computer Graphics Research Group into *The Advanced Computing Center for the Arts and Design*, with funding from a long-term Ohio Board of Regents Academic Challenge grant. ACCAD was established to provide computer animation resources in teaching, research and production for all departments in the College of the Arts at Ohio State.

Movie 4.14 Dawn of an Epoch

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/epochd-1.m4v

Video of CGRG and ACCAD's role in the advancement of computer graphics and animation as it becomes a widely used scientific tool.

During this period, significant research and production was done in the area of animation by many faculty, staff and students, including Joan Staveley, James Hahn (rigid dynamics), David Haumann (flexible dynamics), Chris Wedge, Brian Guenter (parallel graphics), Doug Roble (compositing), Paul MacDougal (levels of detail), Scott Whitman (Parallel algorithms), Beth Hofer (facial animation), Susan Amkraut and Michael Girard (flocking and human locomotion), Midori Kitagawa (Boolean operations), John Chadwick (layered skeleton control of human motion), David Ebert (procedural animation), Jim Kent (3D object morphing), Rob Rosenblum (rendering and animation of hair), and Ferdie Scheepers (animation and modeling of human musculature). The building housing ACCAD (and C/CP) can be seen in the Movie 4.14 as well as in Gallery 4.4 below.

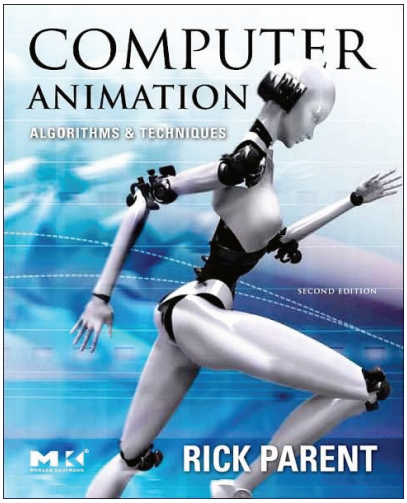
There were also many arts and design students who were involved in award-winning computer animations, and who are now very important educators or animators for the industry. A list of the alumni of the program and their affiliations can be found at the ACCAD web site at

http://accad.osu.edu/people/alumni.html

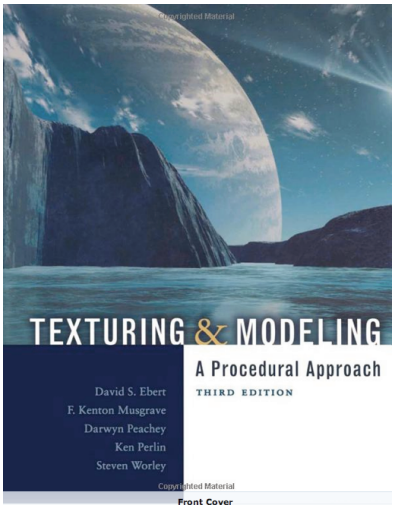
ACCAD was established as an interdisciplinary research center, and was instrumental in many research investigations around computer graphics, animation, visualization, multimedia, etc. A partial listing of the projects and funding can be found on the research section of their website at

http://accad.osu.edu/researchmain/gallery/most-recent.html

Wayne Carlson became the Director of ACCAD in 1991 after Csuri retired. In 2000, Maria Palazzi returned to Ohio State as Associate Director, and in 2001 assumed the Directorship when Carlson became the Chair of the Department of Design at OSU.



Parent book



Ebert book

In 1985 Rick Parent started the CG Lab in the Department of Computer Science in the College of Engineering at OSU. He was later joined by Wayne Carlson, Roni Yagel, Ed Tripp, Kikuo Fujimura, Roger Crafis, and others. Early focus of the lab was on computer animation, particularly character motion, procedural effects, visualization, and geometric modeling. Parent wrote the definitive textbook on computer animation, *Computer Animation, Algorithms and Techniques*, and graduate David Ebert edited the book *Texturing and Modeling*.

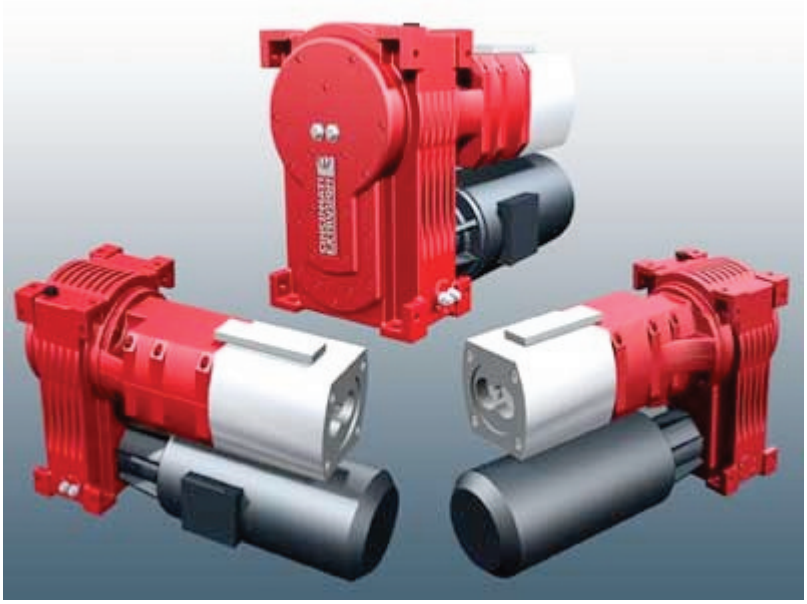
Several influential graduate students came through the CG Lab, some working specifically in the lab, and others also working through ACCAD. For example, Doug Roble won an Academy Award for his work at Digital Domain on motion tracking software; Michael Girard started his own company in 1993, Unreal Pictures, that created the animation software Character Studio, later purchased by Discreet; Dave Haumann was the lead technical director on the 1997 Academy Award winning Geri's Game; Steve May became the Chief Technology Officer for Pixar.

Graduates of the CS program work in many corners of the computer graphics industry, as technical directors in most major production companies, in the game industry, at NVIDIA, Adobe, Sony and other companies, as well as teaching in some of the top universities in the country. More information can be found at the CG Lab *web site*.

Chris Yessios started on the faculty at Ohio State after receiving his graduate degree in 1973 from Charles Eastman's Computational Design Lab at Carnegie-Mellon University, where he became interested in the applications of CAD to architecture. He and his students in the School of Architecture started looking at how this evolving field could be used to impact the way CG and CAD could be used in the design process. At the time, the university was using 2D drafting and 3D modeling programs running on mainframes. Frustrations with the cost of these large computers and some of the emerging turnkey CAD workstations changed when the early Macs became available. They started developing software that would run on the personal computer and provide sophisticated 3D capabilities.



Images source: form·Z Joint Study Journal



In 1990, Yessios and a former student David Kropp, founded AutoDesSys (standing for Automated Design Systems), and developed the popular 3D modeling software, form•Z. They also developed the software products RenderZone and Bonzai3D. The AutoDesSys software was designed to be used in architecture, product design, interior design and illustration applications.

Movie 4.15 Form•Z 2007 User Reel



https://www.youtube.com/watch?v=3PewiPQdA5g

Some Early CGRG and ACCAD videos

Movie 4.16 *Hummingbird* (1966)

Movie 4.17 *Rigid Body Dynamics* (Hahn 1989)

Movie 4.18 *PM Magazine*

Movie 4.19 *Interacting Galaxies* (Reynolds 1977)

Movie 4.20 *Anima II*

Movie 4.21 *The Circus*

Movie 4.22 *Procedural Terrain Models*

Movie 4.23 *Snoot and Muttly* (Van Baerle / Kingsbury 1984)

Movie 4.24 Broken Heart (Staveley – 1988)
http://www.youtube.com/watch?v=iPLFB6_xpAI

Movie 4.25 *Tuber's Two Step* (Wedge – 1985)

Movie 4.26 *Zeltzer SAS V1*

Movie 4.27 *Girard/Karl Creature Motion Studies (1985)*

Movie 4.28 *Eurythmy* (Girard and Amkraut – 1989)

Movie 4.29 *Coredump* (1989)

Movie 4.30 *Tectonic Evolution* (1995)

Art, Computers and Mathematics, by Charles Csuri and James Shaffer, AFIPS Conference Proceedings, V33, FJCC, 1968

Csuri, Charles. *Computer Animation*. Proceedings of SIGGRAPH 75.

Csuri, Charles. Real Time Film Animation, 9th Annual UAIDE Proceedings, 1970.

Rick Parent, *A System for Sculpting 3D Data*, Proceedings of SIGGRAPH 77.

Ron Hackathorn, *Anima II – A 3D Animation System*, Proceedings of SIGGRAPH 77.

Wayne Carlson, Robert Marshall, and Rodger Wilson. "*Procedure Models for Generating Three Dimensional Terrain*," Computer Graphics, V14, #2, July, 1980, pp. 154-161.

C. Csuri, R. Hackathorn, R. Parent, W. Carlson, M. Howard. "*Towards an Interactive High Visual Complexity Animation System*," Computer Graphics, V13, #2, August, 1979, pp. 289-299.

Ohio State Pioneers Computer Animation:Making Birds Fly and Babies Walk. Computer Graphics World article about CGRG by Tom Linehan, October 1985

Csuri, Charles. *Art and Animation*, IEEE Computer Graphics and Applications, January 1991

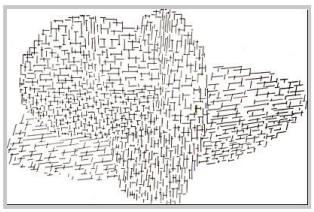
Gallery 4.1 Other Csuri Artwork



Chuck Csuri at CGRG (1978)



Scene from Hummingbird

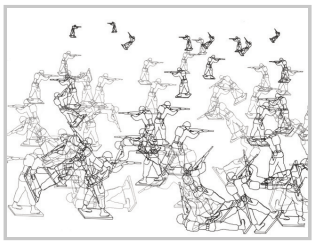


After Mondrian



Shaded Man

Gallery 4.2 Early CGRG Imagery



Random War



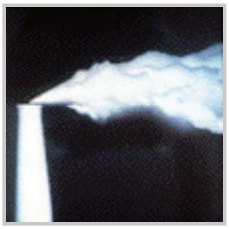
Fall Tree, made with Procedural Modeling



Summer Tree



Forest of Trees



Particle System Smoke Cloud



Patch Intersection Algorihtm

Gallery 4.3 Other CGRG Imagery



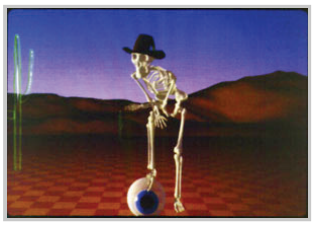
Data made with DG2



Scene from a movie by Frank Crow showing capabilities of the scn_assmblr animation control system.



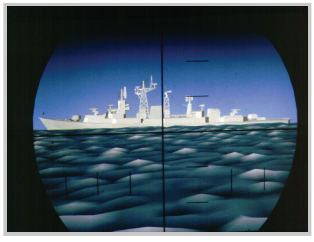
Scene from Snoot and Muttly by Kingsbury and Van Baerle



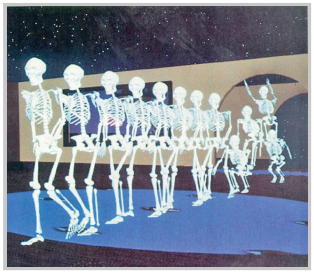
"George in the Desert" – data created by Don Stredney on DG2



Image from paper by Jim Kent – 3D interpolation



Scene from Norfolk ship pilot simulator.

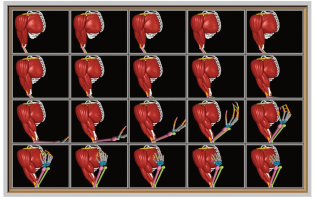


Scene composite from Zeltzer SAS system

Gallery 4.4 CGRG/ACCAD Imagery



Scenes from "Butterflies in the Rain"



Stills from muscle simulation – Ferdie Scheepers and Steve May



Cranston Building, home of CCP and CGRG



CCP lobby

4.6 JPL and National Research Council of Canada



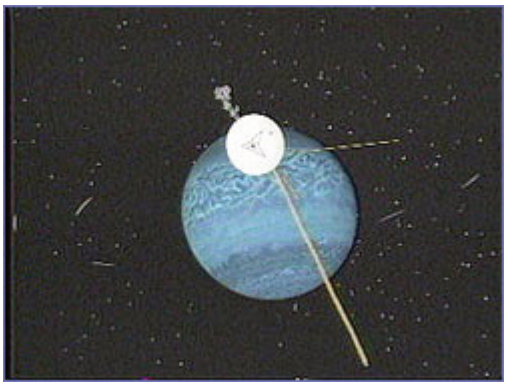
Jet Propulsion Lab (JPL)



Jim Blinn

Bob Holzman established the JPL CG Lab at the Jet Propulsion Lab in 1977. Working with Ivan Sutherland, who had moved from the University of Utah to Cal Tech, Holzman envisioned a group with technology expertise for the purpose of visualizing data being returned from NASA missions. Sutherland recommended a graduate student at Utah named **Jim Blinn**, whose name has become synonymous with JPL and with graphics in general. (Sutherland once allegedly commented that "There are about a dozen really great computer graphics people, and Jim Blinn is six of them.") Several other notable graphics people worked at JPL, including Alvy Ray Smith, Pat Cole, and Julian Gomez.

Blinn received his bachelor's degree in physics and communications science from the University of Michigan in 1970, before computer science was offered as a college subject. He went on to earn a master's degree in engineering at Michigan and a Ph.D. in computer science at the University of Utah in 1977. In 1976 Blinn engaged in an internship at NYIT, where he worked with former classmates, including Ed Catmull, on pressing issues in computer graphics.



Voyager spacecraft



Saturn, as seen from Voyager

Blinn had worked with a wide range of imaging techniques while at Utah, including the design of a comprehensive paint program called *crayon*, and had the vision to develop these techniques into a viable system for the visualization task that Bob Holzman outlined. He arrived at JPL right after the Voyager spacecraft had left for a space review of the outer planets. When he showed up for work at JPL, he was introduced to the work of Voyager Mission Design Manager Charles Kohlhase's work, including an animated line drawing of the Voyager fly-bys. Although it wasn't an official NASA project, Blinn and other JPL staff, including Kohlhase and Pat Cole, produced a series of realistic raster"fly-by" simulations, including the Voyager, Pioneer and Galileo spacecraft fly-bys of Jupiter, Saturn and their moons.

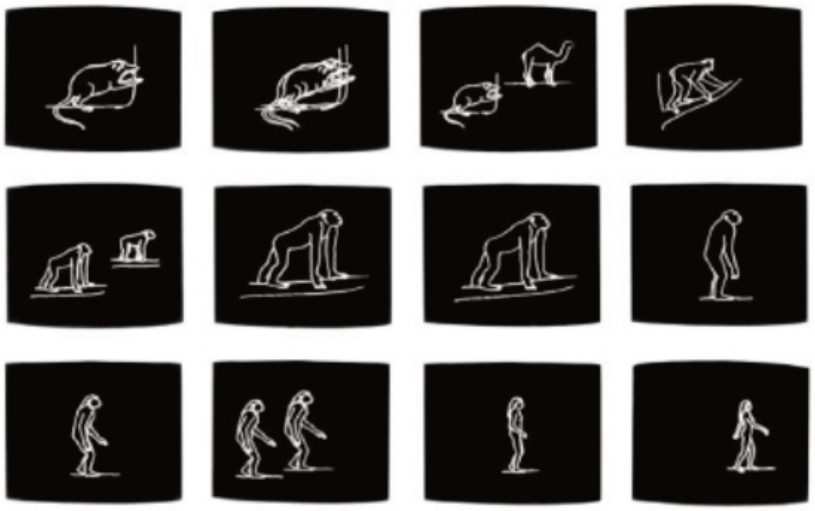
It was stated in an interview with Blinn at *fxguide.com* that he originally used the actual mission planning data to define the path of the spacecraft, and used textures from his paint program to depict surface characteristics. He later replaced them with actual images returned from the spacecrafts. Two of his colleagues from NYIT, Alvy Ray Smith and David Difrancesco helped with responding to NASA requests for a high quality version of his animations, with Smith organizing the camera moves. These animations were so realistic, they became part of the NASA press-kit, and were sometimes interpreted by the public as real movies returned from space.



Kohlhase, Blinn and Cole

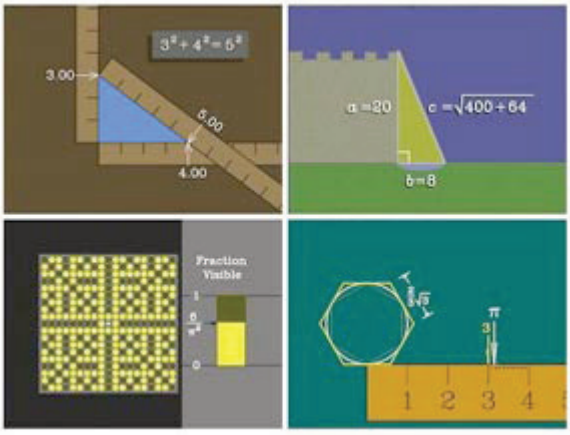
Next, Blinn worked with Carl Sagan on the PBS *Cosmos* series, a 13-part series produced by KCET in Los Angeles. The series was based on Sagan's book *Cosmos: A Personal Journey*, and the value-added was the CG effects from Blinn, and the series won both the Emmy and Peabody awards.

Blinn developed CG sequences for an Annenberg/CPB series, *The Mechanical Universe*, which consisted of over 500 scenes for 52 half hour programs describing physics and mathematics concepts for college students. The real success of this effort was in the explanation of complex science to the general public. In order to produce the detailed CG for these images, he developed new techniques for cloud simulation and a modeling technique variously called metaballs, or what he called "blobby objects."



Scenes from Cosmos

Due to the overwhelming reception of the imagery produced for *The Mechanical Universe*, in 1989 Blinn began production of another series devoted to advanced mathematical concepts. Originally titled Mathematica, the title had to be changed because of a software program called Mathematica for mathematics simulation. The series title was changed to *Project Mathematics!* and was produced largely at CalTech.



Scenes from Project Mathematics!

Holzman, in an *article in 1986 for the Visual Computer*, talked about the hardware environment at JPL:

The hardware system is regular ‘off the shelf’ components assembled to fit NASA’s budget and needs.

The Computer Graphics Lab timeshares on a cluster of two Vax 8600s, two Vax 11/780s, and two Vax 11/750s. One of the Vax 11/780s is allocated for priority processing and the other machines are available for low priority computing during low demand time periods.

A vector display is used as a tool for designing the objects within a scene, and for designing and studying the animation action. Because of its ability to draw 40,000 vectors per second, the vector display is used for previewing action in real time. The third component in the hardware system is the frame buffer (raster display

device) with a resolution of 486 lines and 512 samples of 24 bits each. The device is compatible with video resolution and allows for the use of 16,777,216 colors for full color images. The raster device is used for viewing a fully rendered image on the color monitors and for recording 1″ video tape. (The video equipment came with The Mechanical Universe Project in 1983. Previous animations were made to 16 mm film.)

In 1981 Blinn and Pat Cole left JPL to work at Industrial Light and Magic, but the lure of space visual simulation brought him back to JPL. He later went to Cal Tech, and then Microsoft, where he was involved with the Direct3D project. He received the SIGGRAPH Computer Graphics Achievement Award in 1983, the NASA Exceptional Service Medal for his work on the planetary flyby animations produced at JPL. and the prestigious MacArthur Foundation Fellowship in 1991, and the Coons award from ACM-SIGGRAPH in 1999.

In 1998, Blinn gave the keynote address to the SIGGRAPH 98 Conference in Orlando Florida. In his speech, he reviewed the 25 previous conferences, outlined a number of "unsolved problem" designations, and gave his own accounting of the ten unsolved problems in CG. A slide summary of his address is on the SIGGRAPH 98 website at *http://www.siggraph.org/s98/conference/keynote/blinn.html*

Movie 4.31 *Mechanical Universe*

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/mechanical-2.m4v

This film by Jim Blinn features the animation from The Mechanical Universe. The opening frames are representative of his early work with the spacecraft fly-by animations.

Other JPL Movies

Movie 4.32 *L.A. The Movie (1987)*
and
Movie 4.33 *Mars The Movie (1989)*

Other animations by Jim Blinn

Movie 4.34 Voyager 2 Flyby of Saturn (1981)
https://www.youtube.com/watch?v=SQk7AFe13CY

Movie 4.35 Evolution (1980) – from Cosmos
https://www.youtube.com/watch?v=YEdm1GoUo-o

Movie 4.36 Pioneer 11 Encounters Saturn (1980)
https://www.youtube.com/watch?v=myYIKJF589g

Movie 4.37 Voyager 2 Encounters Jupiter (1978)
https://www.youtube.com/watch?v=o4xIJlEV8Kw

Movie 4.38 Project Mathematics! (1988)
https://www.youtube.com/watch?v=PslowEd4-68

Movie 4.39 Voyager 2 Flyby of Uranus (1986)
https://www.youtube.com/watch?v=DrKQaDupdWQ

Movie 4.40 Computer Visions feature on Jim Blinn (1991)
https://www.youtube.com/watch?v=ePZ301Sg4HI&t=6s

Blinn wrote a series for IEEE Computer Graphics and Applications (for which he received the IEEE Service Award), several books for Morgan Kaufman titled *Jim Blinn's Corner (eg, Ten More Unsolved Problems in Computer Graphics)*, and is the author of many influential papers, including:

Texture and Reflection In Computer Generated Images,
CACM, 19(10), October 1976, pp 542-547.
(The original teapot paper. Introduces environment mapping.)

Models of Light Reflection for Computer Synthesized Pictures,
SIGGRAPH 77, pp 192-198.
(Introduces the Torrance-Sparrow highlight model.)

Simulation of Wrinkled Surfaces,
SIGGRAPH 78, pp 286-292.
(Introduces Bump Mapping.)

A Generalization of Algebraic Surface Drawing,
ACM Transactions on Graphics, 1(3), July 1982, pp 235-256.
(Introduces Blobby Modeling.)

Light Reflection Functions for the Simulation of Clouds and Dusty Surfaces,
SIGGRAPH 82, pp 21-29.
(Lighting model for rings of Saturn.)

National Research Council of Canada

National Research Council of Canada[1] scientist **Nestor Burtnyk** started Canada's first substantive computer graphics research project in the 1960s. **Marceli Wein**, who joined this same project in 1966, had been exposed to the potential of computer imaging while studying at McGill University. He teamed up with Burtnyk to pursue the promising field of applying evolving computer techniques to animation.

The Division of Radio and Electrical Engineering's Data Systems Group wanted to develop ways to make computers easier to use, and it settled on computer animation as the application to pursue after Burtnyk returned from a 1969 conference and heard an animator from Disney studios talk about how cartoons are made. In the traditional process, a head animator draws the key cels or pictures that demonstrate the actions. Assistants then draw the fill in pictures that carry the image from one key picture to the next.

The work of the artist's assistant seemed like the ideal demonstration vehicle for computer animation. Within a year, Burtnyk had programmed a complete "**key frame animation**" package that allowed the creation of animated

1. Portions of the text in this section were taken in part from a press release from the NRC announcing that Wein and Burtnyk were recognized as the "Fathers of Computer Animation Technology in Canada" by the Festival of Computer Animation in Toronto.

sequences by providing only the key frames. The National Film Board in Montreal was contacted, and a project to allow artists to experiment with computer animation was started.

The first experimental film involving freehand drawings, called *Metadata*, was made by artist and animator Peter Foldes. This led to a more substantial collaboration on a 10-minute feature called *Hunger/La Faim* about world hunger and about rich and poor countries.

It took Foldes and his NRC partners a year and a half to make, and in 1974 it became the first computer-animated movie to be nominated for an Academy Award as best short. It received other honors, including the Prix du Jury at the Cannes Film Festival and other international film awards.

Movie 4.41 Excerpt from *Hunger/La Faim*

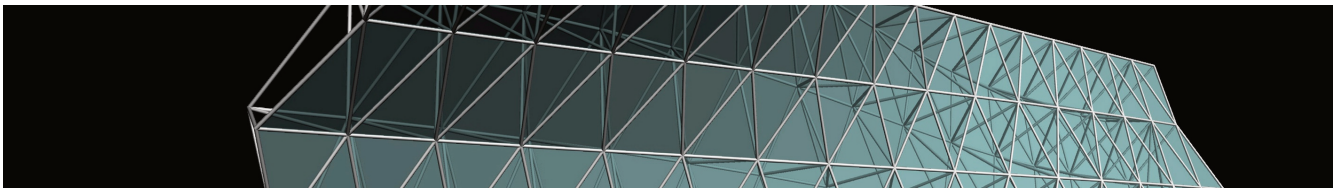
https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/hunger-excerpt.m4v

Hunger, a film by Peter Foldes, can be seen in its entirety at
http://www.youtube.com/watch?v=Vw5fi0iFBDo

In 1996, Burtnyk and Wein received an Academy Award for Technical Achievement for their key-framing animation work.

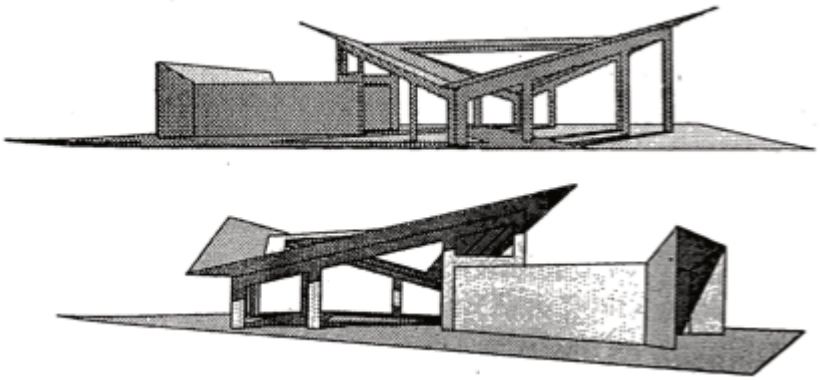
Interactive Skeleton Techniques for Enhancing Motion Dynamics in Key Frame Animation by Nestor Burtnyk and Marceli Wein in Communications of the ACM , October 1976, volume 19 #10, pp. 564-569

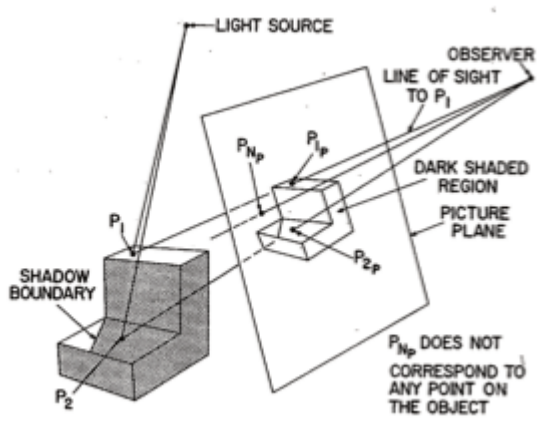
4.7 Other research efforts



Of course, the discussions in the previous sections are not by any stretch of the imagination reflective of all of the research activities taking place in the U.S. or abroad during this early period. For example:

- Work in geometric modeling was being conducted at the Cambridge University CAD lab, with A. Robin Forrest and others. Forrest spent time at Harvard with Steven Coons, and developed a more stable approach to the representation of free-form curves and surfaces, that contributed significantly to CAGD development efforts;
- Arthur Appel and his team of researchers at IBM were developing software and hardware that would not only influence the future CAD industry, but that would affect the CG discipline at large. For example, he contributed to the rendering literature with his research into *hidden line solutions*; he provided what some claim to be the world's first exposure to ray tracing, with his process of determining whether a point was in shadow Images at right); and he introduced the concept of **quantitative invisibility** as an approach to visible surface determination;





- Automotive and aerospace companies, such as GM, Ford, Renault in France (**Pierre Bézier**), Boeing (Ferguson), McDonnell Douglas, and Lockheed Georgia (Chasen) were investigating software solutions for corralling the power of the digital computer for design activities. Chasen was a vocal proponent of the need for graphics hardware companies to develop better technology, and to leave the development of software components to the software industry groups that were much closer to the needs of the users;

Early computer graphics developments in Germany were initiated in Berlin by Wolfgang Giloi when he started there in 1965 in computer graphics GUIs, hardware and software R&D.Two of his former PhD students, Jose Encarnação and Wolfgang Straßer, made substantial contributions to key developments in computer graphics, like Z- buffer and raster technology, device-independent graphics and graphics standards.(See an accounting of this activity in an article on the *Giloi school.*)

Forrest, Archibald Robin.Curves and surfaces for computer-aided design. PhD dissertation, Published 1968 by University of Cambridge

Forrest, Robin. *The Emergence of NURBS*, IEEE Annals of the History of Computing, V20 #2, 1998.

Appel, Arthur. *Some techniques for shading machine renderings of solids*, Spring Joint Computer Conference, 1968 pp 37-45.

Appel, Arthur. *The notion of quantitative invisibility and the machine tendering of solids*, Proc. A.C.M. National Meeting, 1967 pp 387-393.

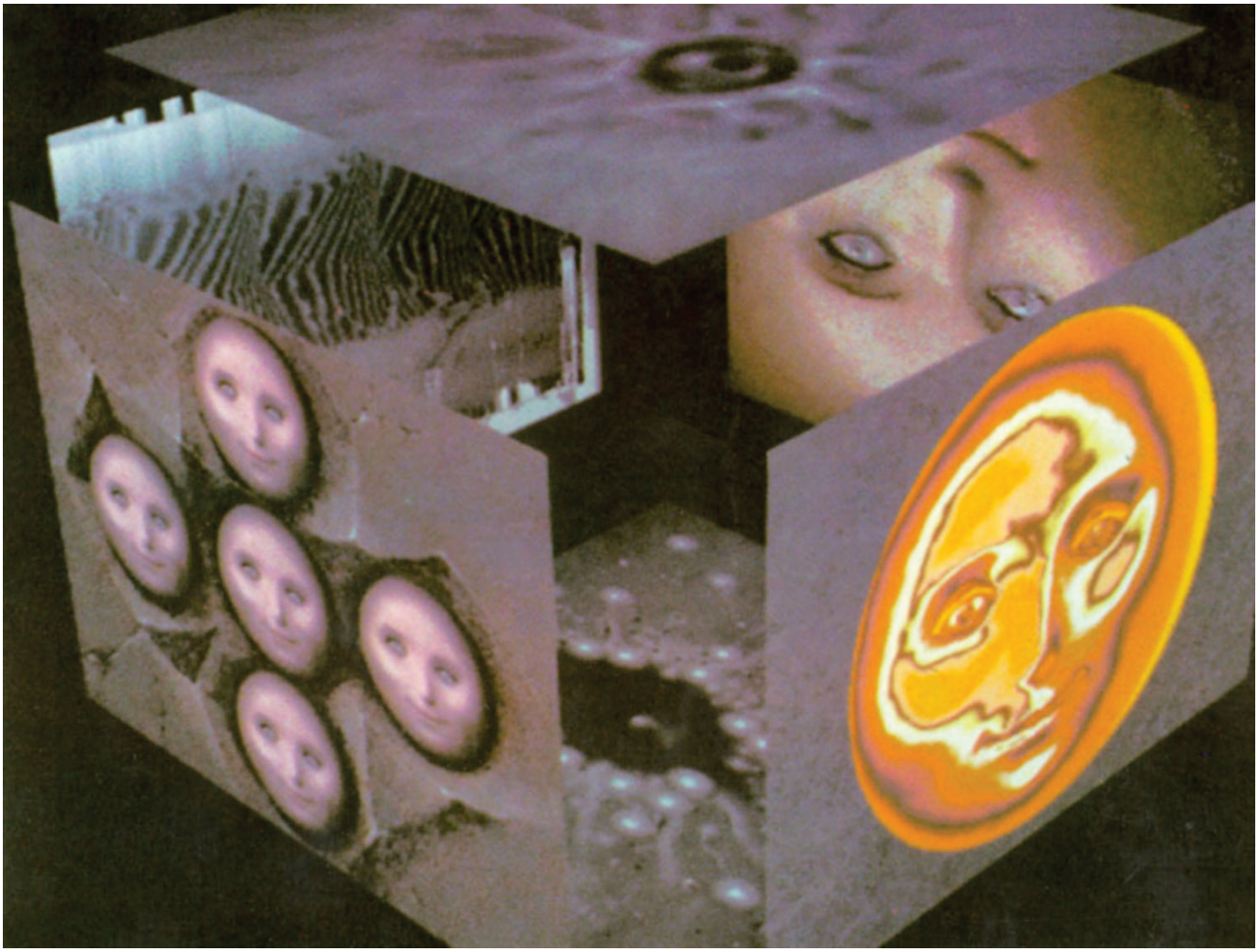
Appel, Arthur, F. James Rohlf and Arthur Stein. *The haloed line effect for hidden line elimination*, Proc. SIGGRAPH 79, pp151-157.

Giloi, Encarnacao and Strasser. *The "Giloi's School" of Computer Graphics.*

Chapter 5: University research labs evolve

University research labs evolve

The federal government and industries interested in the developing area of computer graphics saw the value of basic and applications research to obtain new solutions to problems that existed. Funding for these investigations became a priority, and universities around the world responded by supporting students and faculty. Dedicated laboratories were established, and academic programs grew out of these labs. Several of the early labs have already been discussed (Ohio State, University of Utah, Harvard and MIT). Several more can be considered instrumental in moving the discipline in the 1970s to an established industry beginning in the 1980s.



Sunstone, Emshwiller-NYIT (1979)

5.1 Cornell and NYIT



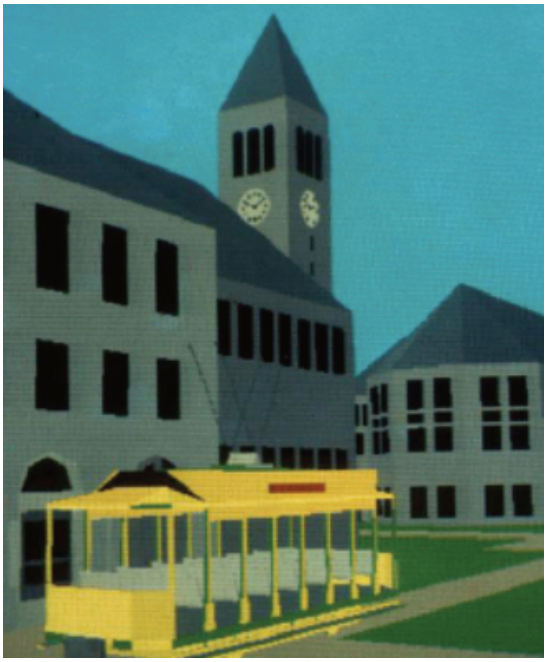
Cornell University



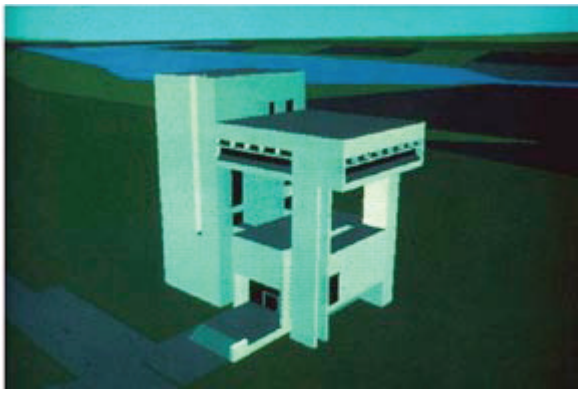
Mosaic of Director Don Greenberg made up of images of former students.?A hi-res image can be seen at? http://erich.realtimerendering.com/DPG/DPG.html

Cornell University, in Ithaca, New York, hosts one of the country's premiere laboratories contributing to the field of computer graphics imagery, the Program of Computer Graphics (PCG), founded in 1974 by the lab's director **Donald P. Greenberg**. The work of Greenberg and his staff and students forms the foundation for many of the practical applications that computer graphics experts and practitioners now routinely use.

Greenberg studied architecture and engineering at Cornell and also at Columbia University. He worked for Severud Associates, an architecture and engineering firm, and was involved with the engineering design of the St. Louis Arch, Madison Square Garden, and other projects.



Images from "Cornell in Perspective

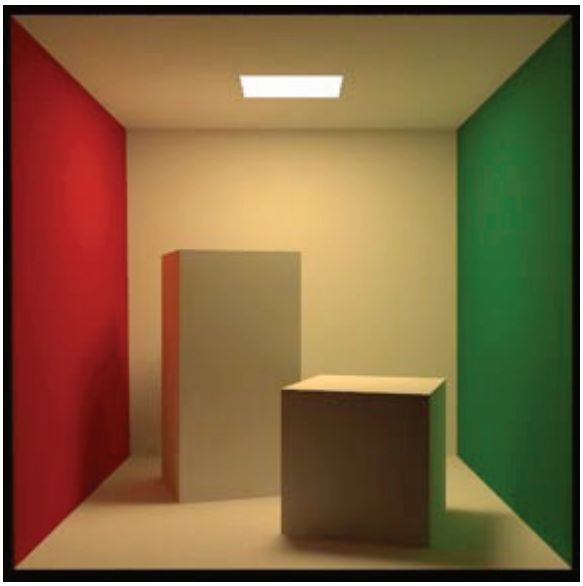




Like many of his contemporaries, the 1960s graphics pioneers in universities across the country, Greenberg saw how the complex engineering applications used by scientists could have an impact on the field of design and art. He received funding from the National Science Foundation to support the theoretical study and practical development of algorithms for the realistic display of images, particularly images of architectural environments.

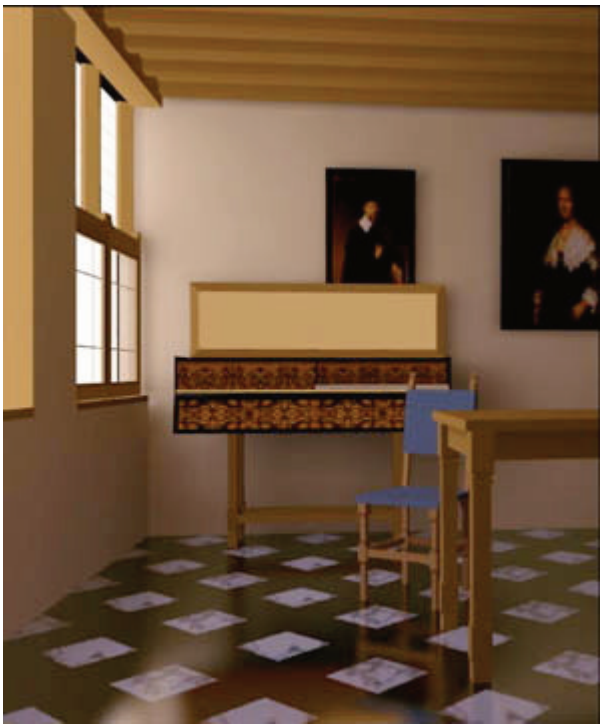
Prior to 1973, much of the research in computer graphics at Cornell was conducted at a General Electric research facility in Syracuse. Greenberg and his students would travel to Syracuse to arrive as the normal workday ended, and leave when the machines were needed by GE again the following morning.

The Program of Computer Graphics received its first National Science Foundation grant in the fall of 1973, which enabled Greenberg to order the lab's first computer graphics equipment. That equipment arrived early in January of 1974, and the first facility was set up in Rand Hall on the Cornell Campus. Greenberg published a *paper at SIGGRAPH 77* describing the Cornell Lab.



The Cornell Box

The Cornell PCG is best known for pioneering work on realistic image synthesis, including the **radiosity** method for calculating direct and indirect illumination in synthetic scenes. The long-term goal of the lab was to develop physically-based lighting models and perceptually based rendering procedures to produce images that were visually and measurably indistinguishable from real-world images. The work of the faculty and students has spawned much of the accurate lighting capabilities now present in commercial software. Roy Hall was instrumental in the development of the Abel Image Research raster system, and contributed to the Wavefront renderer (he also wrote the important book *Illumination and Color in Computer Generated Imagery*, published by Springer-Verlag in 1989.) The popular renderer Lightscape was also a result of Cornell research.



The Vermeer Studio

Since its founding the lab has researched and refined a framework for global illumination incorporating light reflection models, energy transport simulation, and visual display algorithms. The goal was to solve these computationally demanding simulations in real time using an experimental cluster of tightly coupled processors and specialized display hardware. They are achieving this goal by taking advantage of increased on-chip processing power, distributed processing using shared memory resources, and instructional-level parallelism of algorithms. The graphics research also involved three-dimensional modeling of very complex environments and new approaches for modeling architectural designs.

In 1991, the Program of Computer Graphics moved to the new Engineering and Theory Center Building across campus, now renamed Rhodes Hall as a tribute to Dr. Frank H.T. Rhodes, the former president of Cornell. Also in 1991, Cornell became one of five universities participating in the new National Science Foundation Science and Technology Center for Computer Graphics and Scientific Visualization (see Section 5 in this Chapter.) The *list of Cornell alumni* reads like a who's who in graphics, and the research publications coming from the lab are some of the most significant contributions of any lab in the world.

Greenberg received the ACM-SIGGRAPH Coons award in 1987 for his lifetime contribution to computer graphics and interactive effects.

Movie 5.1 Cornell in Perspective

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/cip-2.m4v

In 1971, Greenberg produced an early sophisticated computer graphics movie, Cornell in Perspective, using the General Electric Visual Simulation Laboratory.

Some of this material was taken from an article in *Architecture Week* about the graphics program at Cornell, and from the history of the *Program of Computer Graphics* on Cornell's web site.

Cornell was one of 12 research labs showcased in an exhibition at SIGGRAPH 98 for the 25th anniversary of the conference. Their portion of the exhibition can be found at *http://www.graphics.cornell.edu/siggraph/1998images.html*

Donald P. Greenberg, *An Interdisciplinary Laboratory for Graphics Research and Applications*, Proceedings of the Fourth Annual Conference on Computer Graphics, Interactive Techniques and Image Processing – SIGGRAPH, 1977

Cornell student Marc Levoy did his Bachelors and Masters work around 2D cartoon animation. His work led to a production system at Hanna Barbera Productions. As Levoy stated in an interview related to the Sands Award given for the best undergraduate research work in 1976:

> "After the completion of my Master's thesis, Don Greenberg and I tried to convince the Walt Disney's feature animation group to incorporate computer graphics into their production process. Unfortunately, several of the "nine old men", who had worked for Disney since the 1930's, were still active, and they would have none if it. By the mid-1980's, these gentlemen had all retired, and Pixar was able to convince Disney to explore the new technology. The system they co-developed was called CAPS (Computer Animation Production System). It ultimately won them an academy award in 1992 for its use in Beauty and the Beast.
>
> Although we were unsuccessful at Disney, we managed to convince Hanna-Barbara[sic] Productions

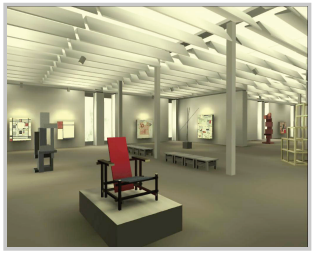
to employ our system in the television animation market. Hanna-Barbara was on the verge of closing down domestic production due to spiraling labor costs, and they saw our system as a way to forestall doing this. The animator's union didn't believe them, nor did they relish the prospect of computerization, leading to a bitter strike in 1982. In the end, the animators learned to use our system, which remained in production until 1996. At its peak in the late 80's, one third of Hanna-Barbera's yearly domestic production went through our system, including The Flintstones, Scooby Doo, and other shows. Ultimately, domestic labor costs become too high even for the computerized production line, and the the system was sold to James Wang Films of Taiwan. It has since been ported to PCs and is currently marketed under the name Animaster. The original technical team at Hanna-Barbera Productions consisted of myself, Bruce Wallace, Chris Odgers, Bennett Leeds, Jim Mahoney, Steve McDaniel, and Tim Victor. Our chief power user from the production side of the company was Ann Tucker. Interestingly, Ann subsequently went to work for Disney, becoming their chief power user as well."

Levoy worked as director of the Hanna-Barbera Animation Laboratory from 1980 to 1983.

Gallery 5.1 Cornell PCG Images



Frank Lloyd Wright's Fallingwater by Matt Hyatt and Stephen Holley of the Cornell University Program of Computer Graphics. The building's first floor is the centerpiece of the model. Comprised of 150,000 triangles and numerous texture maps, it is used to test global illumination algorithms.



Rendered using radiosity techniques developed at Cornell University PCG. The image appeared on the proceedings cover of SIGGRAPH 1988.



Keith Howie of the Cornell PCG modeled this Hewlett-Packard 800 series workstation in 1989. This image appeared on the cover of IEEE Computer Graphics & Applications in January, 1991. A version of this image also appears in the back of Computer Graphics, Principles and Practice, by Foley, van Dam, Feiner and Hughes.



Dani Lischinski, Filippo Tampieri and Donald P. Greenberg created this image for the 1992 paper Discontinuity Meshing for Accurate Radiosity. It depicts a scene that represents a pathological case for traditional radiosity images, many small shadow casting details. Notice, in particular, the shadows cast by the windows, and the slats in the chair.



The Magritte Studio by Michael Cohen (1985) of the Cornell Program of Computer Graphics. This image was created using the hemi-cube algorithm developed at Cornell.



The Radiosity Factory from Cornell University. This image was rendered by Michael F. Cohen, Shenchang Eric Chen, John R. Wallace and Donald P. Greenberg for the 1988 paper A Progressive Refinement Approach to Fast Radiosity Image Generation. The factory model contains 30,000 patches, and was the most complex radiosity solution computed at that time. The radiosity solution

took approximately 5 hours for 2,000 shots, and the image generation required 190 hours, each on a VAX8700.



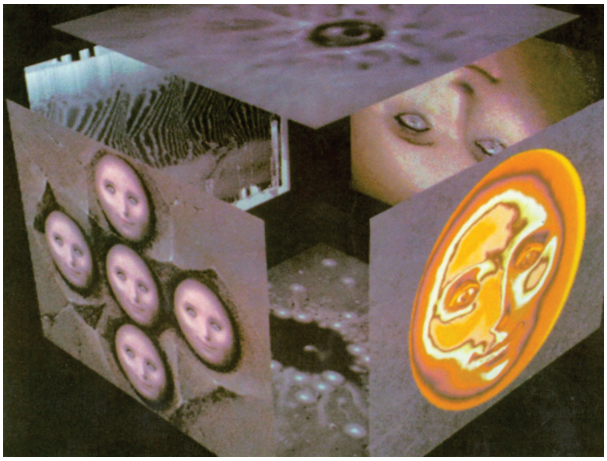
CG image of a samovar vase created at Cornell PCG.

New York Institute of Technology (NYIT)

Alexander Schure, a wealthy entrepreneur from New York, was interested in making a feature length movie, and after attempting the process with traditional animation, became enamored with and wanted to use computers to do it.

In 1953 Schure got into the business of providing veterans with correspondence courses, and in 1960 his school was accredited as New York Institute of Technology, or NYIT. Expanding his campus from NewYork City, he bought an old industrialist estate in Westbury on Long Island in 1963. His first movie attempt was in the early 1970s, a traditional animation project called *Tubby the Tuba*, which ultimately failed miserably.

Schure's board of directors included members of the wealthy Rockefeller family, who also served on the board of the computer graphics company Evans and Sutherland in Utah. In 1974, Dr. Schure made a commitment to the computer film project by establishing the *Computer Graphics Laboratory* (CGL) at NYIT. The Rockefellers suggested that he visit E&S in Utah to get a sense of the kinds of technology that was available. He put together one of the most sophisticated studios of the time on the NYIT campus on Long Island, employing CGI equipment and state of the art computers that he obtained from E&S, but also top end analogue devices for doing special effects. He also was interested in top talent, and looked to the University of Utah to find this talent after having been exposed to the animated face and hand produced by Ed Catmull and Fred Parke. He hired Catmull (who had left Utah for the CAD company Applicon) and fellow Utah grad Malcolm Blanchard to run his facility, and they were soon joined by Alvy Ray Smith and David DiFrancesco, and later Lance Williams, Fred Parke, Garland Stern, and others, including many from Utah. He also attracted other technology experts and artists, including Jim Clark, Ralph Guggenheim, Ned Greene, Rebecca Allen and Ed Emshwiller, who was a Hugo award winning artist who had recently won a Guggenheim grant to make a film. Emshwiller worked with Stern, Williams and Smith and other NYIT staff to make the now famous film *Sunstone* in 1979.

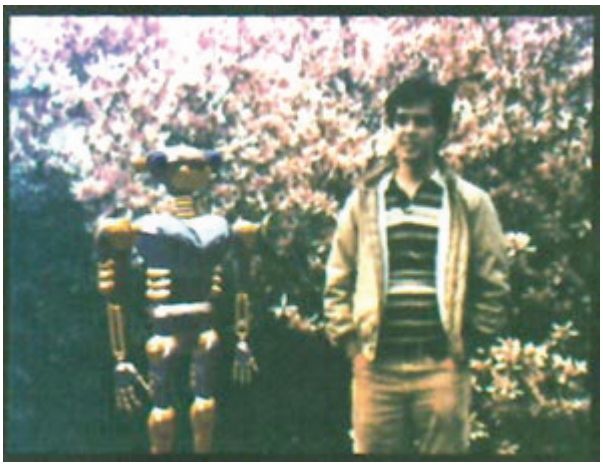


Frame from Sunstone

The personnel at NYIT CGL were very prolific in the design of influential software during the period from 1975 to 1979, including the animation program *Tween*, the paint program *Paint*, the animation program *SoftCel*, and others. They also contributed to image techniques involving *animation*, fractals, morphing, *image compositing*, texture mapping (the famous *Mip-Map* approach), digital conversion of video signals, scanning of animated frames, and many other innovations.

The NYIT staff, most notably Gene Miller, Lance Williams and Michael Chou, were responsible for an innovative rendering technique called "**reflection mapping**", which was later used to provide realism to shiny objects in television and the movies (eg, *Flight of the Navigator, Terminator,* and *The Abyss*).

One of the first such images (shown here) was done by Chou, showing him standing next to a shiny synthetic robot. NYIT published the technique at SIGGRAPH in 1982 and 1984, and in 1985 used the technique in a short video titled *Interface*.



Michael Chou and his robot

Another innovation out of NYIT, arguably one of the most influential, was the **alpha channel**. This contribution made it possible to combine two images or parts of images, and to recognize the impact of transparency in the combination. As Alvy Ray Smith said in his 1995 technical memo, *Alpha and the History of Digital Compositing*

"Ed Catmull and I invented the notion of the integral alpha in the 1970s at New York Tech. This is the notion that opacity (or, equivalently, transparency) of an image is as fundamental as its color and should therefore be included as part of the image, not as a secondary accompaniment. To be very clear, we did not invent digital mattes or digital compositing. These were obvious digital adaptations of known analog techniques. We invented the notion of the alpha channel as a fundamental component of an image. We coined the term 'alpha' for the new channel. We called the resulting full-color pixel an 'RGBA' pixel."

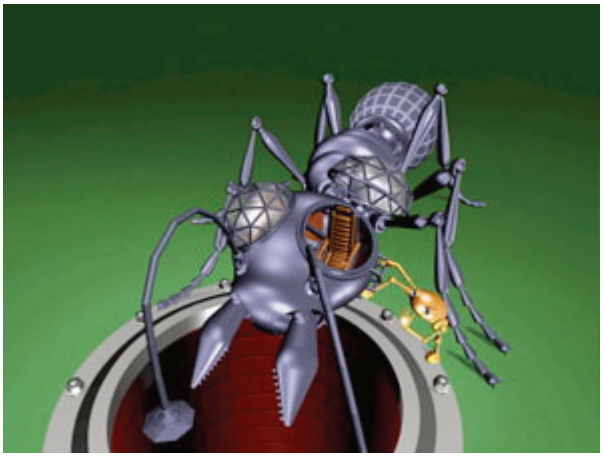
Alpha compositing was further developed in a *1984 paper* by Tom Porter and Tom Duff at Lucasfilms.

Smith developed the 8-bit program *Paint*, which was sold to Ampex and became the main components of the Ampex AVA system. This system was used by artist LeRoy Niemann to do interactive painting during Superbowl XII in 1978. *Paint* and Smith's later 24-bit *Paint3* had a great deal of influence on subsequent systems, including the paint system at Lucasfilm and the CAPS system developed for Disney by Lucasfilm.

After *Tubby the Tuba* failed in the way that it did, many of the traditional animation staff left NYIT, and the emphasis on 3D moved forward. CGL worked on highly visible ads and television promotions for clients such as NOVA and ABC Sports.

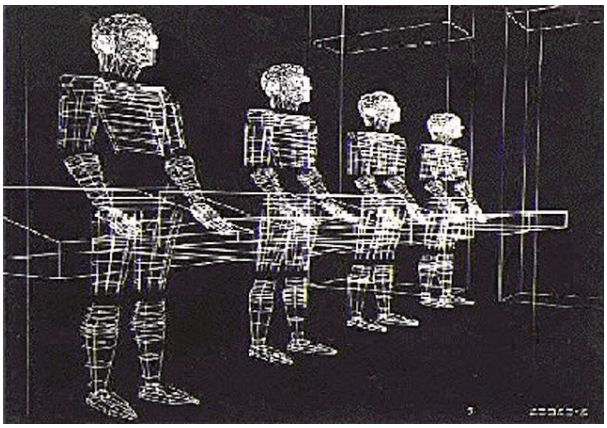
Several videos from NYIT have become quite famous: *Sunstone*, *Inside a Quark*, by Ned Greene, and *The Works*, as well as some documentary work by Rebecca Allen. A great deal of effort at NYIT went into the development of the film "*The Works*", which was written by Lance Williams[1]. For many reasons, including a lack of film-making expertise, it was never completed. Sequences from the work in progress still stand as some of the most astounding animated imagery of the time.

Many of the researchers at CGL were becoming disillusioned with Schure and the way he ran the facility, so they quietly looked for different opportunities elsewhere. The quality of the imagery, along with the other research and technology work at NYIT attracted the attention of George Lucas, who was interested in developing a CGI special effects facility at his company Lucasfilm. He sent one of his top people, Richard Edlund, to scope out what was going on at the Long Island lab. He soon after recruited much of the top talent from NYIT, including Catmull, and Smith and Guggenheim (who both took on a short stint at JPL) to start his division, which eventually was spun off as Pixar.



An article on The Works was featured in the trade magazine Computer Pictures in 1983

1. Lance Williams passed away on August, 20, 2017. Hank Grebe, who worked with Williams at NYIT, eloquently paid tribute to him with a quote of the last paragraph of "The Works" script: *"Beeper and Ipso gazed at the ship landing on the screen , and the boy and the robot and the vastness of the Works itself dwindled to tiny points on the earth, and the earth, to a tiny point among the stars, and the stars lost their identity in clouds of galaxies, and when the inconceivably vast clusters of the galaxies are indistinguishable in the milky swirl of the infinity of space, some people will still be wondering if the Universe is large enough to include a story as unlikely as this one."*



Scene from Kraftwerk music video – Rebecca Allen

Work continued after the departure of some of the originators of the CGL facility. Rebecca Allen, who came to NYIT from MIT, won an Emmy for work done for *Walter Cronkite's Universe*, and she later did several music videos, including work for Kraftwerk and Peter Gabriel. The French company Thompson Digital Image, or TDI, bought the rights to use Garland Stern's system BBOP, as did Omnibus in Canada.

Schure never got over the move of his top talent from NYIT, and he attempted to obtain patents on many of the innovative algorithms that were developed there by them. He was unsuccessful, in large part because he was so late in filing, because many had been published at SIGGRAPH and elsewhere, and because Microsoft and Pixar fought those attempts. Schure eventually succumbed to Altzheimer's disease in 2009.

Ed Catmull and Lance Williams received the ACM-SIGGRAPH Coons award in 1993 and 2001 respectively, for lifetime contribution to computer graphics and interactive effects. Williams also received an Academy Award for Technical Achievement in 2002 for his influence in the field of computer generated animation and effects for motion pictures. Garland Stern received an Academy Award for Technical Achievement in 2001 for the Cel Paint Software System. Alvy Ray Smith received the ACM-SIGGRAPH Computer Graphics Achievement award in 1990 for an outstanding contribution to computer graphics and interactive effects. He also received an Academy Award for Technical Achievement in 1997 for his paint system.



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(027)

A New York City office of NYIT's CGL was established to market and sell the technology developed in Westbury. Also called CGL, it focused on the emerging television advertising and promotions industry. CGL sold hardware and licenses to the *Images* and *Images II* production systems to many other companies, including Omnibus in Toronto and JCGL in Japan.

Movie 5.2 Sunstone



Sunstone (1979) Ed Emshwiller (with Alvy Ray Smith, *Lance Williams, Garland Stern)* *http://www.youtube.com/watch?v=tMW15OajuKc*

Movie 5.3 Excerpt from *The Works*

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/works.m4v

Movie 5.4 The Works (1984)
http://www.youtube.com/watch?v=18OSLeWJVJQ

Movie 5.5 Kraftwerk *Musique Non Stop* music video
graphics by Rebecca Allen
http://www.dailymotion.com/video/x175jh_kraftwerk-music-non-stop_music

Movie 5.6 JCGL Demo Reel 1983
https://www.youtube.com/watch?v=_WlAnrdtGmg

Porter, Thomas, and Duff, Tom, *Compositing Digital Images*, Computer Graphics, Vol 18, No 3, Jul 1984, 253-259. SIGGRAPH'84 Conference Proceedings.

Smith, Alvy Ray, Image Compositing Fundamentals, Tech Memo 4, Microsoft, Jun 1995.

Smith, Alvy Ray, *Alpha and the History of Digital Compositing*, Tech Memo 7, Microsoft, Aug 1995.

An article on The Works was featured in the trade magazine *Computer Pictures* in 1983.

A great compilation of NYIT information can be found at Paul Heckbert's site at *http://www.cs.cmu.edu/~ph/nyit/*.

Alvy Ray Smith wrote an article describing the Paint program as part of a survey of activities related to digital ink and paint called *Digital Paint Systems*, a Microsoft Technical Memo.

Alvy Ray Smith wrote an interesting account of he and Ed Emshwiller and the creation of Sunstone, now at the computer history site, and can be read at http://www.computerhistory.org/atchm/alvy-ed/

Heckbert wrote a personal account of the participation of the NYIT staff in the making of the IMAX movie "*The Magic Egg*" for the 1984 SIGGRAPH conference in Minneapolis.

A 2007 NYIT Alumni article titled "Out of this World: Meet the NYIT scientists and alumni who amazed Silicon Valley, astonished Hollywood and engineered the 3-D computer animation universe" can be accessed here.

In 1989, Quantel, Ltd. filed suit in British courts accusing Spaceward, Ltd. of violating their claim to have invented digital "airbrushing" and digital compositing. Alvy Ray Smith testified as to his development of the concepts earlier than the claim of Quantel, but to no avail. Spaceward lost the case, and their product. Smith commented, in his paper *Digital Paint Systems: An Anecdotal and Historical Overview*, in 2001, that he had done this work while at NYIT in 1977: "To my mind, airbrushing and digital compositing are the same thing: One combines one image with another, using a third for transparency control."

In 1996 a patent infringement case was again filed by Quantel Ltd. against Adobe Systems, Inc., accusing Adobe Photoshop's "paint" feature of infringement. A jury ultimately found Quantel's patents invalid because they covered basic software techniques developed in 1977 by Alvy Ray Smith, a computer graphics pioneer and co-founder of Pixar Animation Studios. Smith had sold his paint system to Ampex in the mid 1970s and briefly described his digital paint systems in "tutorial notes" distributed at conferences in 1978. The source code that implemented Smith's paint systems was not itself readily accessible, yet it is fair to say modern computer graphics evolved, in large part, from Smith's groundbreaking work.
From T*aking Care of Business – Patent reform should promote innovation, not imitation*, by Kelly C. Hunsaker. San Francisco Chronicle, August 30, 2005

This case was documented in an article in Computer Graphics in August, 1998, *Computer graphics in court: the Adobe/Quantel case*, by Dick Phillips.

The results of the case were outlined in a 1997 article, Adobe Defeats Infringement Claim, found at *http://www.litstrat.com/Cases/ADOBEtest.pdf*

Gallery 5.2 NYIT Image Collection



Image created with Paint

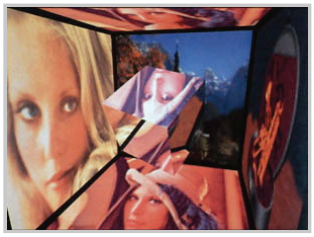
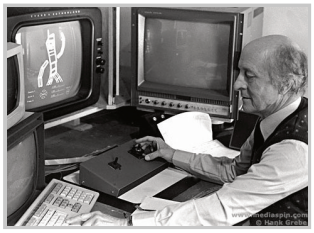


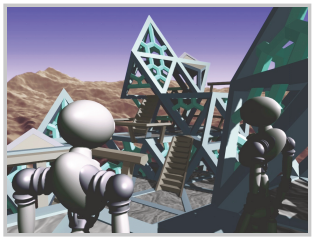
Image transformation



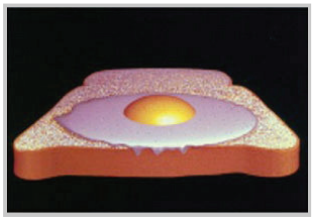
Arthur Clokey, the creator of Gumby, works on the E&S graphics display, which was the heart of the NYIT CGL system. to create a digital version of the popular character (Hank Grebe and Dick Lundin, 1984)?For more information from http://www.mediaspin.com/gumby.html



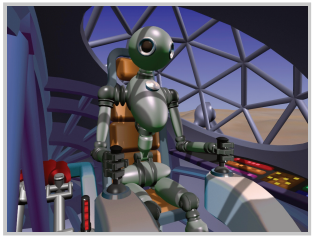
Raspberries of Kyoto – Peter Oppenheimer



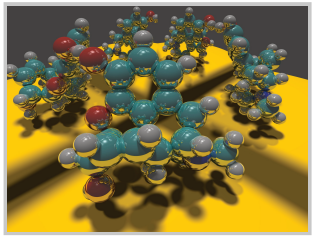
Mondo Condo – Ned Greene



Paint image – Alvy Ray Smith



Driver (Ant Jockey) from the Works – Dick Lundin and Ned Greene (1983)



Ray tracing with soft shadows – Paul Heckbert



Scene from Kraftwerk music video – Rebecca Allen



Saxobone (1982) – Dick Lundin



Synthesized maple tree – Jules Bloomenthal



Dimetrodon – Dick Lundin

5.2 UNC and Toronto



UNC

Henry Fuchs arrived at the University of North Carolina at Chapel Hill in 1978, after completing his PhD at the University of Utah.[1] His early work was in the area of binary space partitioning (BSP) trees for optimal determination of visibility in computer generated scenes, 3D data acquisition and construction, and moved to high performance architectures for graphics and hardware visualization techniques. He was appointed the Federico Gil Professor of Computer Science and adjunct professor of radiation oncology, after starting in computer graphics and image processing in 1969. Prof. Fuchs served on the editorial board of ACM Transactions on Graphics from 1983 to 1988, and was the guest editor of its first issue (January 1982). Fuchs received the 1992 Computer Graphics Achievement Award from ACM-SIGGRAPH and the 1992 National Computer Graphics Association Academic Award. He was also selected as an ACM Fellow.

In 1980, the faculty and students at the Graphics and Image Analysis Research center at UNC began exploring computer architectures for 3D graphics that were significantly faster than traditional architectures for applications that required high performance, such as medical visualization. The project that Fuchs started was called Pixel-Planes, and had an emphasis on scalability and real-time rendering.

The principle techniques used revolved around a plane of processors, each with a few bytes of its own memory, operating in unison. Each pixel (picture element) on the screen was associated with a unique processor. Since each processor knew its x and y screen coordinates, the system sent out the equation for a line and each processor computed which side of the line it was on. Sending the equations for three lines allowed for the computing of which processors were inside the lines and how far away from the viewer's perspective each pixel was. The shading and texturing each of the pixels was done in a similar rapid manner.

The first machine built at UNC under the project was Pixel-Planes 2. Its screen resolution was 4×64 pixels, and only 16 bits of memory per pixel, and was only able to display a few polygons per second. Yet, even with those

1. Much of this account is taken from the lab description at the UNC website.

statistics, this early prototype showed the power of the concepts. Pixel-Planes 4 was a machine that had an array of 512×512 processors operating in synchrony. Each pixel processor had 72 bits of memory at its disposal. The video image was produced directly from what is stored in the memory, and a front-end processor based upon a Weitek chip set performed the initial geometry computations, the results of which were fed to the processor array. This machine could draw at the rate of about 40,000 triangles per second. Pixel-Planes 5 solved some of the problems of Pixel-Planes 4, such as the idleness of the processors when computing images comprised of small polygons.

Instead of a single 512×512 array, it had multiple 128×128 arrays (up to about 20 of them). Each of the processors had 208 bits of primary memory available, plus 4096 bits of secondary memory. In addition, instead of a single geometry processor, there were many (up to about 50) Intel i860 processors. Rather than generate the video image from the memory of the processor arrays, the data was sent to a separate frame buffer. This also allowed the use of multiple frame buffers of various types, including a high resolution (1280×1024) model. The net result of the system was a rendering rate of over 2 million triangles per second.

The next generation machine, PixelFlow (PxFl) used pairs of geometry processors and array processors working independently to create screen-sized images based on the subset of the triangles that they have. The partial images were then combined into one by performing a depth-wise sort using a special high-speed image composition network.

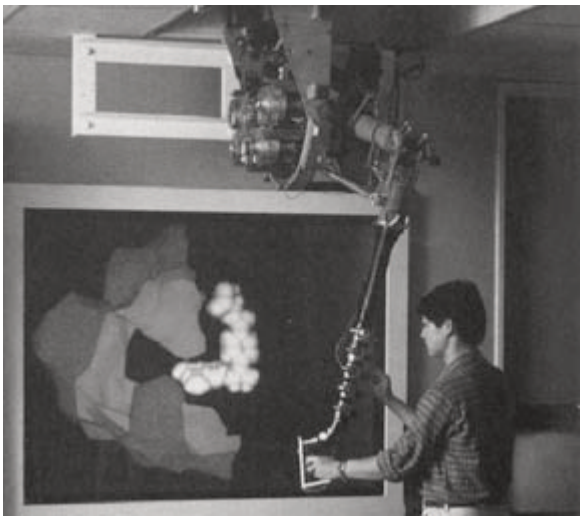


The nanoManipulator

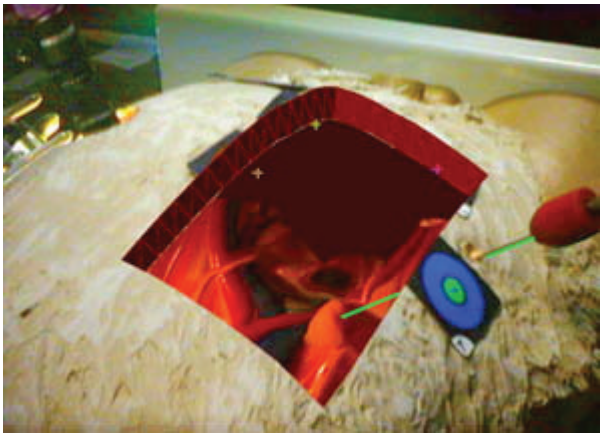
Besides Pixel-Planes, the UNC group worked on virtual environments and other related projects. Fred Brooks, who started the Computer Science Department at UNC in 1964 oversaw that work. Brooks' contributions were broad, from computer architecture, to human computer interaction, to virtual environments. He was widely published (he was the author of the excellent book, *The Mythical Man Month* (1975)). He received many awards for his activities, including the National Medal of Technology, the A.M. Turing Award from ACM, John Von Neumann Medal from IEEE, and was both an ACM Fellow and an IEEE Fellow. Brooks' research on real-time, three-dimensional computer graphics propelled that field forward, driven by the goal of creating tools that enabled scientists and engineers to tackle problems formerly beyond their reach.

The UNC team built the first molecular graphics system on which a new protein structure was solved. They also first proved that **haptic** displays augmenting visual displays could significantly improve a scientist's understanding of data.

Brooks was assisted on the research for VR and haptics by Mary Whitton and others. They developed several systems, including Grip, Grope and Docker. They connected haptic feedback to the microscope, and extended it to passive haptics for determining feel such as standing on a ledge.



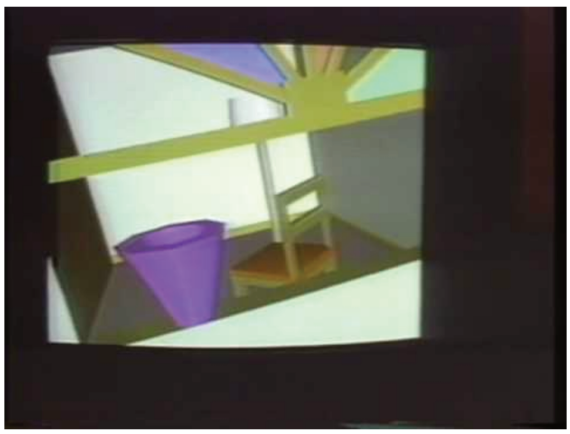
The Docker haptic feedback system



Augmented Reality ultrasound visualization

The ultrasound research group at UNC developed a *prototype real-time augmented reality system* based on an SGI Onyx workstation equipped with a real-time video capture unit. The camera captured both HMD camera video and ultrasound video. The camera video was displayed in the background; the ultrasound video images were transferred into texture memory and displayed on polygons emitted by the ultrasound probe inside a virtual opening within the scanned patient. This system was used to demonstrate the possibility of using augmented reality to enhance visualization for laparoscopic surgery.? (Portions of the above text were taken from the UNC Computer Science research webpages.)

Movie 5.7 Pixel Planes



Pixel Planes 4 was one in a series of graphics systems developed at the University of North Carolina in the 1980s. https://www.youtube.com/watch?v=7mzpZ861wEw

Henry Fuchs list of graphics publications can be viewed online at *http://www.cs.unc.edu/~fuchs/publications2011.html*

A summary of publications from the UNC research projects can be viewed online at *http://telepresence.web.unc.edu*

University of Toronto

The University of Toronto Dynamics Graphics Project (*dgp*) was founded in 1967 by Professor Leslie Mezei. He was joined by Professor **Ron Baecker** in 1972, who coined the name Dynamic Graphics Project in 1974, when they got their first stand-alone machine, a PDP11/45 with a highly-interactive display informally called the Graphic Wonder. Baecker had completed his PhD in 1969 at MIT, working on the *GENESYS animation system*.

The *dgp* lab's name was intended to imply the spirit of the place, and to encompass both Computer Graphics and Dynamic Interaction Techniques, which was subsumed by the new field of Human Computer Interaction in the early 1980's. Under the leadership of Baecker, Alain Fournier, Bill Buxton, and Eugene Fiume, *dgp* became a world academic leader in both computer graphics and human-computer interaction. The lab's alumni are now on faculty at top universities throughout the world and at major industrial research labs, and have also won academy awards for their groundbreaking work.

Other early work included the Smalltalk animation system SHAZAM. An early animated film done by Baecker called *Sorting Out Sorting* showed the value of animation in teaching complex concepts.

The *dgp* at Toronto was very closely tied to the development efforts at Alias, headquartered in Toronto (see more about Alias in Chapter 8.) As was stated in the document referenced at the beginning of this section:

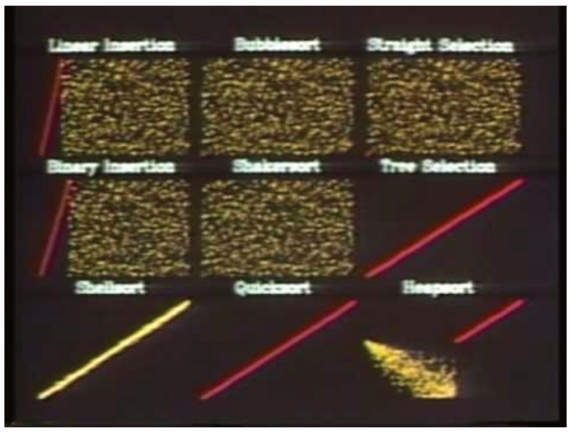
"The *dgp*-Alias partnership began in 1992. Alias was recovering from a financial downturn with renewed investments in R&D for computational tools for design and entertainment. Computational power had by then reached the stage where high-quality interactive graphics was within reach, but a great deal of basic research was still needed. Alias collaborated with various universities on mathematical techniques for modeling surfaces, and on animating and rendering geometric models. However, the modeling of natural phenomena such as smoke, fire, clouds and water was embryonic research. By 1994, Eugene Fiume and his then student Jos Stam demonstrated a new way to model "gaseous and fluid phenomena" that was then licensed by Alias. Stam and Fiume worked with engineers from Alias to integrate these techniques into the Alias design product with astonishing success: the enhanced product drew considerable attention from film animators, and the (now) world- renowned animator, Chris Landreth, while working at Alias, used this technology often in completely unexpected ways to create an Academy Award nominated film called "the end". Dozens of film productions used this work in short order, routinely including Landreth himself, who ten years later won an Academy Award in 2005 for his beautiful

film “Ryan”. This film incidentally also involved members of *dgp*. Jos Stam joined Alias and continued a string of innovations that make him among the most highly cited researchers in computer graphics. His efforts were recognized in a “Computer Graphics Achievement Award” presented by the premier organization in the field, ACM SIGGRAPH. After more years of enhancement, Stam and his colleagues at Alias won a Technical Academy Award for their fluid simulation software. The story has come around full circle, as Stam is now an Adjunct Professor in the Department of Computer Science at the University of Toronto, working with several students in *dgp*.

Likewise, in the early 1990s, Gord Kurtenbach developed an innovative user interface dialogue technique called “Marking Menus” as part of his Ph.D. work in *dgp* under the supervision of **Bill Buxton**. This technology was also transferred to Alias and became central to distinguishing the workflow and user interface of Alias from its competitors. Both Buxton and Kurtenbach then joined Alias, forming the core of a new research group at Alias. This was among the first groups in industry to focus on fundamental research on human-computer interfaces and on usability engineering. The group, strengthened by more *dgp* graduates such as George Fitzmaurice and Russell Owen, quickly established an international reputation in HCI, publishing a series of highly cited papers. Bill Buxton went on to become a Chief Scientist of the company.

Fiume joined Alias for several years starting in 1995, going on to establish broadly based Research and Usability Engineering department. This set the stage for a similar growth in computer graphics research as Buxton spearheaded in HCI: Karan Singh and Jos Stam joined the research group, developing new techniques in geometric modeling, deformations, and the modeling of natural phenomena. When Fiume returned to the University of Toronto to chair the Department of Computer Science in 1998, Kurtenbach took over as Director of Research, and both Kurtenbach and Fitzmaurice became Adjunct Professors in the department. By then the Alias Research group was a world leader in both HCI and computer graphics.”

Movie 5.8 Sorting Out Sorting (Excerpt)



“Sorting Out Sorting” was developed to visualize the processes used in different data sorting algorithms.
https://www.youtube.com/watch?v=gv0JUEqaAXo

Baecker, R.M. (1969). Picture-Driven Animation. Proceedings of the AFIPS Spring Joint Computer Conference, 273-288.

Baecker, Ronald M. (1969). Interactive Computer-Mediated Animation. PhD Thesis, MIT. *http://www.lcs.mit.edu/publications/pubs/pdf/MIT-LCS-TR-061.pdf*

Baecker, R.M., Smith, L., and Martin, E., *GENESYS – An Interactive Computer-Mediated Animation System*, system demonstration film, MIT Lincoln Laboratory, 1970.

Buxton, William (2005). Interaction at Lincoln Laboratory in the 1960's: Looking Forward — Looking Back. Panel Introduction. Proceedings of the 2005 ACM Conference on Human Factors in Computing Systems, CHI'05, April 3-7, 2005, 1163-1167. *http://billbuxton.com/LincolnLab.pdf*

5.3 Cal Tech and North Carolina State



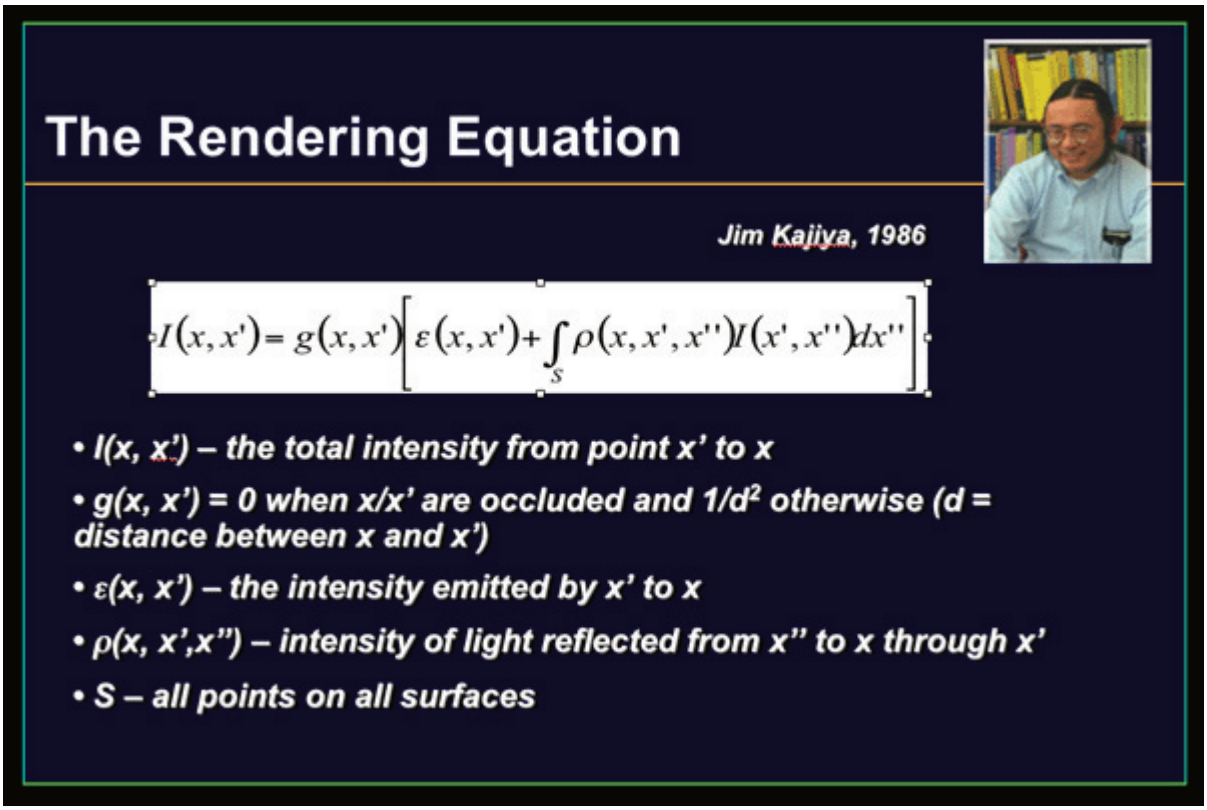
Cal Tech

The Computer Science Department at Cal Tech was started in 1976 by Robert Cannon, then U.S. Assistant Secretary of Transportation for Systems Development and Technology. He organized a search committee to recruit top faculty to the new department, and one of his first recruits was Ivan Sutherland (who was appointed as the Fletcher Jones Professor of Computer Science). **Jim Kajiya** was recruited by Sutherland in 1979, and they were later joined by **Al Barr** and Jim Blinn, who with Kajiya formed the core of the Cal Tech research group in computer graphics, which was probably the most mathematically sophisticated computer graphics group in the country. The group developed fundamental mathematical approaches for computationally simulated physical objects.?? Barr's work in graphics was dedicated to creating a unified mathematical formalism for representing the shape and the behavior of objects. Kajiya was working toward connecting computer graphics principles to the basic equations of electromagnetism that govern the behavior of light. Blinn was recruited to Cal Tech as a half-time research fellow (later lecturer) by Sutherland. His primary interest was in the space program, and Blinn spent the other half of his time at the Jet Propulsion Laboratory producing animated simulations of the Voyager missions to Jupiter and Saturn.

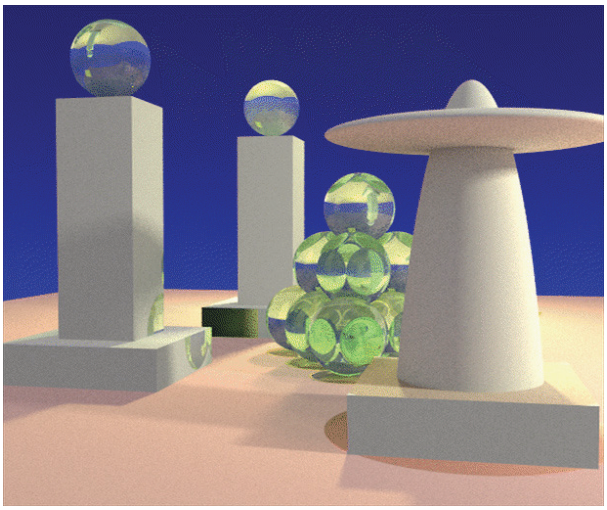
Kajiya had a Utah PhD, but his fields of interest were very high-level programming languages, theoretical computer science, and signal processing. His interest in computer graphics began in 1981, after he presented a paper at the national SIGGRAPH conference on different ways of manipulating pixels (individual picture elements) to get a sharper image in the display of characters on CRT screens. Kajiya met Al Barr in the summer of 1983, when they were both speakers at the SIGGRAPH seminar on the state of the art in computer graphics. At that time Barr was senior research scientist at Raster Technologies, Inc. and was finishing his thesis at Rensselaer Polytechnic Institute. He was about to accept a faculty position at MIT, but Kajiya convinced him to come to Cal Tech instead.

Kajiya was also interested in **anisotropic reflection**, that is, reflection from surfaces such as cloth, hair, or fur. They worked on the mathematical methods used for the what Kajiya called the "fuzzy object problem", the

simulation of hair, fire, fabric, and splashing water, as well as simulating the shapes and appearance of plants and animals. The group also produced 4 out of the 19 contributions to the 1985 **Omnimax** film shown at SIGGRAPH 95. Barr animated a giant school of graceful sperm cells swimming toward a looming, "undulating egg cell", and JPL's Jeff Goldsmith, with software by Kajiya and Blinn, contributed a fly-by of Saturn. The third film was a sequence based on the constellations, with software written by Blinn. Kajiya, with computer science grad students Tim Kay and Brian Von Herzen, together with help from Art Center students, contributed a 30 second animation of a flight into a space colony (which just happened to house the Cal Tech campus).



1986, Kajiya introduced *the rendering equation* as a way of modeling global illumination in an environment arising from the interplay of lights and surfaces. The rendering equation and its various forms have since formed the basis for physically-based rendering, enabling a new level of realism.



Caustics and color bleeding

Other Cal Tech researchers besides Kay and Von Herzen included Andrew Witkin, David Kirk, Kurt Fleischer, Ronen Barzel, David Laidlaw, John Platt and others. Jim Kajiya received the ACM-SIGGRAPH Graphics Achievement Award in 1991 for an outstanding contribution to computer graphics and interactive effects. He and Tim Kay also received an Academy Award for Technical Achievement in 1996 for their work in generating fur and hair for motion pictures. A list of publications out of the Cal Tech Graphics group can be found at *http://www.gg.caltech.edu/publications.html*

Cal Tech was one of five universities (Brown, UNC, Utah, Cornell, and Cal Tech) across the country that were part of the NSF funded Graphics and Visualization Center, founded in 1991. It was one of 24 National Science Foundation Science and Technology Centers created to pursue foundational interdisciplinary research. The primary goals of the Center were to build a stronger scientific foundation for computer graphics and scientific visualization and to help create the basic framework for future interactive graphical environments (see section 5 in this chapter.)

Research Areas

The Cal Tech Computer Graphics Group pursued research in four main areas of computer graphics, with a focus on the mathematical foundations of CG: modeling, rendering, user interfaces and high-performance architectures. Two driving application areas helped direct this research: scientific visualization and telecollaboration in virtual environments. Center researchers developed new rendering algorithms based on the physics of light, new physically-based models, sophisticated mathematics for 3D surface definition, new parallel display architectures, easier-to-use 3D user interfaces for individual and collaborative work on the desktop and in virtual environments, and new techniques for scientific visualization.

Books (*) and selected publications

*Barzel, Ronen. *Physically-Based Modeling for Computer Graphics: A Structured Approach*. San Diego: Academic Press, 1992. Abstract is available

*House, Donald and David Breen, eds. *Cloth Modeling and Animation*. Natick, MA: AK Peters, 2000.

*Kirk, David, ed. *Graphics Gems III*. San Diego: Academic Press, 1992.

*Snyder, John M. *Generative Modeling for Computer Graphics and CAD: Symbolic Shape Design Using Interval Analysis*. San Diego: Academic Press, 1992. Abstract is available.

Kajiya, James T., "The rendering equation," in *Proceedings of SIGGRAPH 1986*, ACM SIGGRAPH, 1986, pp. 143-150.

Witkin, Andrew, Kurt Fleischer and Alan H. Barr, "Energy constraints on parameterized models," in *Proceedings of SIGGRAPH 1987*, ACM SIGGRAPH, 1987, pp. 225-232.

Terzopoulos, Demetri, John Platt, Alan H. Barr and Kurt Fleischer, "Elastically deformable models," in *Proceedings of SIGGRAPH 1987*, ACM SIGGRAPH, 1987, pp. 205-214.

Barzel, Ronen and Alan H. Barr, "A modeling system based on dynamic constraints," in *Proceedings of SIGGRAPH 1988*, ACM SIGGRAPH, 1988, pp. 179-188.

Snyder, John M., "Interval analysis for computer graphics," in *Proceedings of SIGGRAPH 1992*, ACM SIGGRAPH, 1992, pp. 121-130. Abstract is available.

Snyder, John M. and James T. Kajiya, "Generative modeling: a symbolic system for geometric modeling," [Figures], in *Proceedings of SIGGRAPH 1992*, ACM SIGGRAPH, 1992, pp. 369-378. Abstract is available.

Fleischer, Kurt W., Bena Currin, David H. Laidlaw and Alan H. Barr, "Cellular texture generation," in *Proceedings of SIGGRAPH 1995*, ACM SIGGRAPH, 1995, pp. 239-248.

Greenberg, Donald, Kenneth Torrance, Peter Shirley, James Arvo, et al., "A framework for realistic image synthesis," in *Proceedings of SIGGRAPH 1997*, ACM SIGGRAPH, 1997, pp. 477-494.

North Carolina State University

The graphics program at North Carolina State University was relatively short-lived, but the investigations that were conducted there had long term impact on the discipline. Prof. John Staudhammer (later with the Graphics Symbolic and Geometric Computation Program at NSF) created the research group in the Electrical Engineering Department around 1970. Students included Turner Whitted, Nick England, Mary Whitton, Jeff Eastman, Marc Howard, Ed Tripp and others. They had some success with research publications, and developed some lasting hardware configurations.

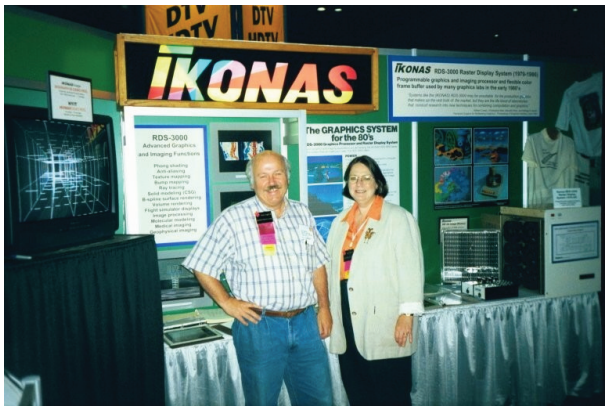


Nick England uses a RAND tablet with one of the NCSU raster displays

Eastman, Dave Wooten, and Tripp designed a very fast asynchronous parallel processor for graphics operations, and England designed and built the fore-runner to the Ikonas system, a programmable 32-bit graphics processor (based on AMD 2901) and a frame buffer (512x512x2 or 256x256x8), which was published in a paper at SIGGRAPH 78.

Staudhammer formed a company called Digitec and built the real-time playback run-length encoded frame buffer for the CGRG at Ohio State, and Whitton and England started Ikonas Graphics Systems based on the England's programmable raster display processor.

After receiving his PhD from NCSU in 1978, **Turner Whitted** left for Bell Labs and proceeded to impact the CGI world with an algorithm that could **ray-trace** a scene in a reasonable amount of time. His film, *The Compleat Angler* is one of the most mimicked pieces of CGI work ever, as nearly every student that enters the discipline tries to generate a bouncing ray-traced ball sequence. Whitted was also very instrumental in the development of various scan line algorithms, as well as approaches to organizing geometric data for fast rendering.



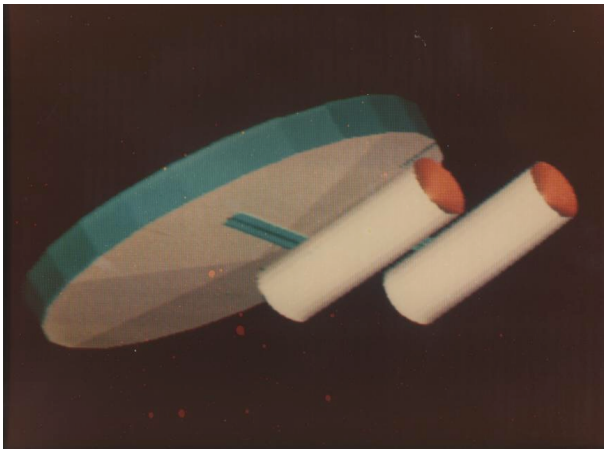
Nick England and Mary Whitton at the Ikonas booth at SIGGRAPH 98

In 1983, Whitted left Bell Labs to return to North Carolina to establish Numerical Designs, Ltd. (later part of Emergent Game Technologies) in Chapel Hill. NDL was founded with Robert Whitton of Ikonas to develop graphics toolkits for 3D CGI. Key developments of NDL included

- NetImmerse 3D Game Engine
- MAXImmerse 3D Studio MAX Plug-in
- PLUS Photorealistic Rendering Software

Whitted also had a faculty appointment at UNC, and in 1997 joined the graphics division at Microsoft. He was appointed an ACM Fellow, and received the 1986 SIGGRAPH Graphics Achievement award for his simple and elegant algorithm for ray-tracing. He became the lead contact for the Graphics group and the Hardware Devices group at Microsoft, where he investigated alternative user interface devices, such as wearable interfaces.

Movie 5.9 NC State graphics



Early computer graphics at NC State University Signal Processing Lab – circa 1973
https://www.youtube.com/watch?v=4MHzU4xJ4pk

1984 article about Computer Graphics at Cal Tech
https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/caltech-graphics1984.pdf

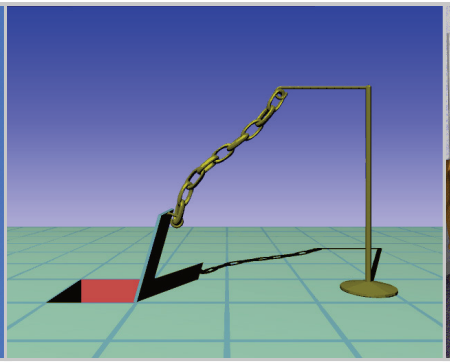
An extensive list of Cal Tech books and publications can be found online at
http://www.gg.caltech.edu/publications.html

For more information about the early work at NCSU, see *Nick England's NCSU page*.

Gallery 5.3 Images from Cal Tech



Herbert the Bear with 3D textures



Pandora's Chain – Al Barr – CalTech



Living room – lighting and shadows



Generative modeling (Image appears on the cover of John Snyder's book)



Fleischer – Developmental modeling

5.4 Illinois-Chicago and University of Pennsylvania



University of Illinois – Chicago Circle



Dan Sandin

Dan Sandin came to the University of Illinois at Chicago Circle from the University of Wisconsin in 1971 and developed the Sandin Image Processor, which could be thought of as the visual counterpart to the **MOOG synthesizer**. He was joined the next year by **Tom DeFanti**, who had developed the Graphics Symbiosis System (GRASS) as part of his PhD work with Chuck Csuri at the CGRG at Ohio State. Together, they organized the Circle Graphics Habitat, which became an environment for experimental computer graphics, video production, and educational materials development. Later in 1987, they were joined by Maxine D. Brown as Associate Director.

Some of the most important early work at the Habitat revolved around the Z Box (Z-50 processor) project, which resulted in the development of ZGRASS, which was an early PC-based graphics system for the Bally computer (1981). In the words of Jane Veeder, it provided

"…real time animation and real time sound synthesis accessed by a custom language optimized for interactive artmaking, all wrapped up together like a hot little sports car."

The box had an NTSC video output port, which provided video recording and display capabilities for artists. DeFanti et al attempted to commercialize the product through their company, Real Time Design, Inc. Artist Larry Cuba produced an animated sequence for the movie *Star Wars* on the system at Chicago in 1977.



Tom DeFanti

Later contributions were in mathematics visualization and virtual reality, including the *CAVE environment* and the Immersadesk. DeFanti also contributed immensely to the SIGGRAPH organization, as its President and with contributions to their annual conference. DeFanti and the group at Chicago began a project to archive all of the films and videos shown at the SIGGRAPH conference, resulting in the SIGGRAPH Video Review (SVR). The Circle Graphics Habitat later became the Electronic Visualization Lab (EVL).

Research work at EVL over the years has included[1]:

- 1977: The Sayre Glove, the first dataglove.
- 1981: The Z Box hardware and ZGRASS software (based on DeFanti's prior GRASS programming language), an early graphics system for the Bally home computer. This system featured NTSC video output and was used by a number of computer graphics artists of the time.
- 1988: Computer generated PHSColograms, an autostereoscopic 3D technique, with $(art)^n$.
- 1992: The CAVE Automatic Virtual Environment, a projection-based virtual reality system.
- 1995: The I-WAY event at Supercomputing '95, a prototype of grid computing.
- 1997: The STAR TAP project, a linking up of several international high-performance networks. Followed by the StarLight optical networking facility.

Highlights of the electronic art work done at EVL include:

- Electronic Visualization Events (EVE) in the mid 1970s – live, real-time performances featuring computer graphics, video processing, and music.
- Early computer graphics art videos, created by combining DeFanti's GRASS system on a PDP-11 and the Sandin Image Processor. The video *Spiral PTL* (1980) was included in the inaugural collection of video art at the Museum of Modern Art.
- Computer artist Larry Cuba spent time at EVL, using the tools there for his films *3/78* and *Calculated Movements*, as well as a short special effects sequence for Star Wars.
- In 1996, EVL installed the first publicly accessible CAVE at the Ars Electronica Center in Austria, and presented a number of virtual reality artworks.

1. From the EVL Wikipedia page at https://en.wikipedia.org/wiki/Electronic_Visualization_Laboratory

University of Pennsylvania

Norman Badler received his PhD at the University of Toronto. He joined the faculty of the University of Pennsylvania in 1974, and started the Computer Graphics Research Laboratory in the Computer and Information Science Department (in 1994 the lab became the Center for Human Modeling and Simulation). Research focused on his research emphasis on human figure animation, including human figure modeling, manipulation, and animation control, embodied agents, intuitive user interfaces, and computational connections between language and action. An early contribution with Maxine Brown and Steve Smoliar was in the area of *Laban Notation* scripting for animation. The lab achieved international recognition for its research and specifically for the *Jack software* (later marketed as a commercial product by Engineering Animation, Inc.).



Scene from the Jack software display

Jack provided a 3-D interactive environment for controlling articulated figures. With his human-like ability to reach and grasp as well as detect and avoid "collisions" with objects in his virtual environment, Jack could be animated to perform a variety of tasks that engineers could observe and evaluate. Jack featured a detailed human model who behaved realistically in various virtual environments. Designers could test the reach, range of motion, and other features of any size human, as he or she would fit within a designed space. For example, engineers would use Jack to determine whether crucial instruments within an aircraft cockpit fall within comfortable reach of the pilot, thus saving time and expense in building prototypes.

L. Weber, S. Smoliar, and N. Badler. "*An architecture for the simulation of human movement*." Proc. ACM National Conf., Washington, DC, Dec. 1978

C. Phillips and N. Badler. " *Jack: A toolkit for manipulating articulated figures*." ACM SIGGRAPH Symposium on User Interface Software, Banff, Canada, October 1988, pp. 221-229.

Simulating Humans: Computer Graphics Animation and Control, by Norman I. Badler, Cary B. Phillips, and Bonnie Lynn Webber, Oxford University Press, Jun 17, 1993 – 270 pages

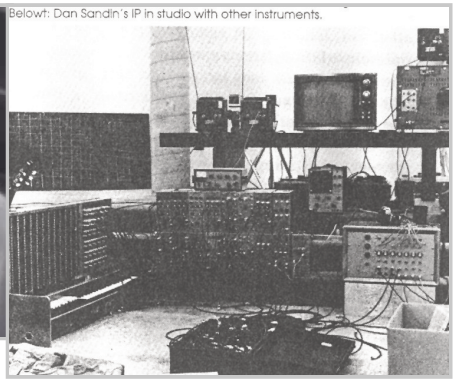
Gallery 5.4 Circle Graphics Habitat



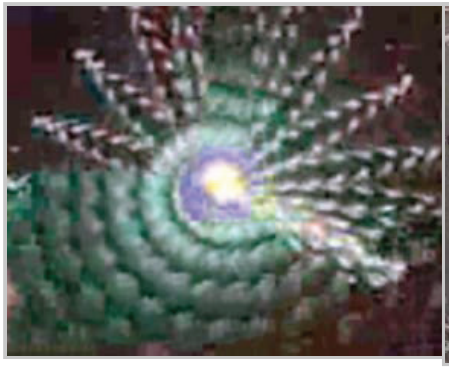
Dan Sandin and Tom DeFanti



Dan Sandin



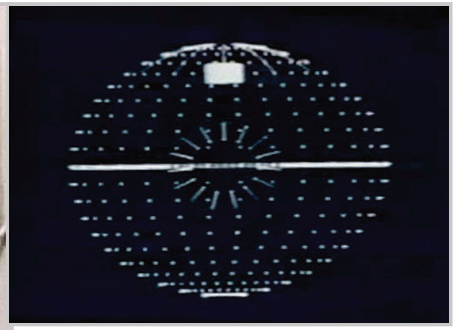
Equipment in the DeFanti/Sandin laboratory at the Circle Graphics Habitat at the University of Illinois at Chicago Circle.Source: http://www.audiovisualizers.com/toolshak/vidsynth/sandin/sandin.htm



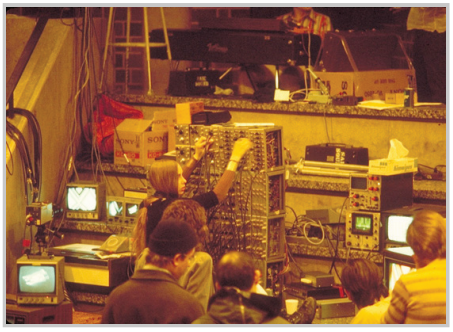
Scene from Spiral 5



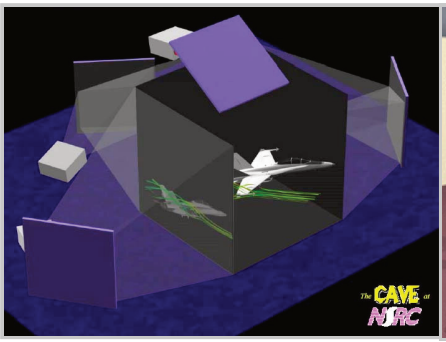
Fabricated Grass computer



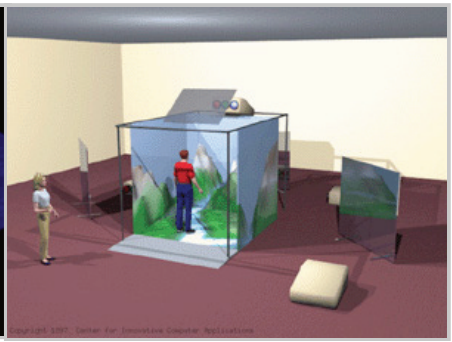
Scene from Larry Cuba's Star Wars animated sequence – 1977



Circle Graphics Habitat – 1973



A diagram of the CAVE at the National Supercomputing Research Center (NSRC). The CAVE (CAVE Automatic Virtual Environment) was developed by DeFanti, et al at the University of Illinois. This CAVE installation is an enclosed 10 feet cube room-sized advanced visualization tool that combines high-resolution, stereoscopic projection and 3D computer graphics to create the illusion of complete immersion in a virtual environment.



CAVE installed at IU

5.5 Other labs and NSF Technology Center



There are quite a number of other universities that also contributed to the advancement of the discipline at this point. For example, these three programs were major contributors to the discipline.

Hiroshima University

Eichachiro Nakamae and his group at the EML at Hiroshima University in Japan conducted research on lighting and atmospheric scattering of light. Eichachiro Nakamae later became chairman of Sanei Co. and an honorary professor of Hiroshima University. He was appointed as a researcher associate at Hiroshima University in 1956, a professor from 1968 to 1992 and an associate researcher at Clarkson College of Technology, Potsdam, NY, from 1973 to 1974.



Eichachiro Nakamae

Carnegie Mellon University

The appointment of Charles Eastman in 1968 to the faculty of what were then the Departments of Architecture and Computer Science at Carnegie Mellon University initiated a series of research projects that were seminal to the field of computer-aided architectural design. Eastman, at the Institute for Physical Planning at Carnegie Mellon, developing the GLIDE system with Max Henrion and the General Space Planner (GSP) System, a software system for solving space planning problems. Eastman and Kevin Weiler also published a seminal paper on the use of **Euler operators** for geometric modeling. Subsequent



Charles Eastman

research activities concentrated on a general modeling scheme for buildings. Chris Yessios, developer of Form•Z at Ohio State, received his doctorate from this program.

Brown University

Andy Van Dam created the program at Brown University, and has over 3 decades of contributions in the area of graphical user interfaces (more information on Brown can be found in the section on GUIs in Chapter 16).



Andy Van Dam

NSF Center



In 1991, The National Science Foundation funded the NSF Science and Technology Center for Computer Graphics and Scientific Visualization, as a consortium of five of these important universities (Cornell, Brown University, the University of North Carolina at Chapel Hill, the University of Utah, and Cal Tech).The original mission of the NSF Center, to rebuild the foundations of computer graphics, became even more important in the years after the Center was established. In addition, the center served as an experimental collaboration environment among the five universities, linked by full-time video, audio and data connections used for teaching, administration, and research. Close ties among the members influenced the research and broadened the exposure the graduate and undergraduate students at each facility, and in fact at all other academic research facilities received.

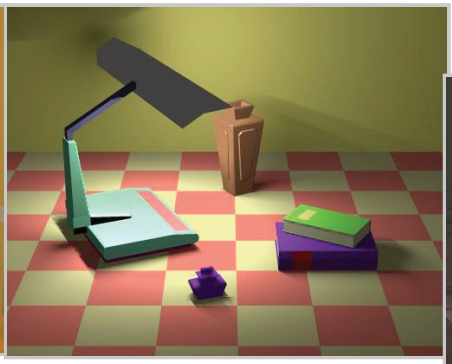
Gallery 5.5 Hiroshima University

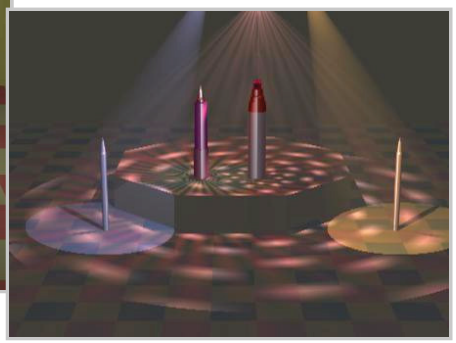


Linear light source

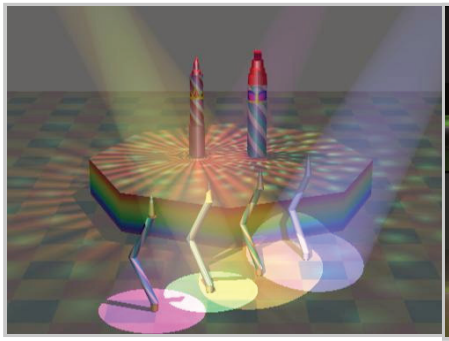


Light and shadows





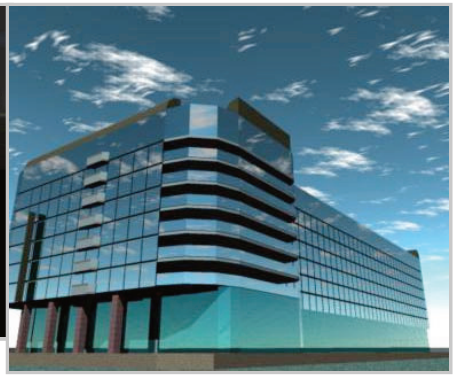
Frame from Feast of Light



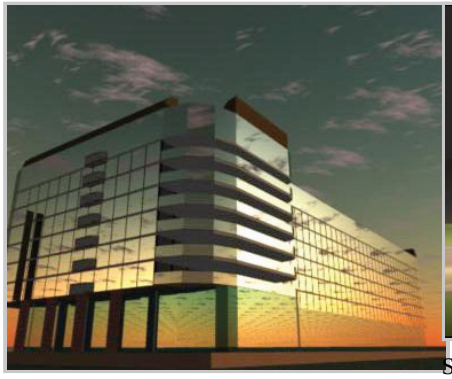
Frame from Feast of Light



Scene from Visitor on a Foggy Night



Daytime light reflections



Evening sun reflection



Scene from Visitor on a Foggy Night

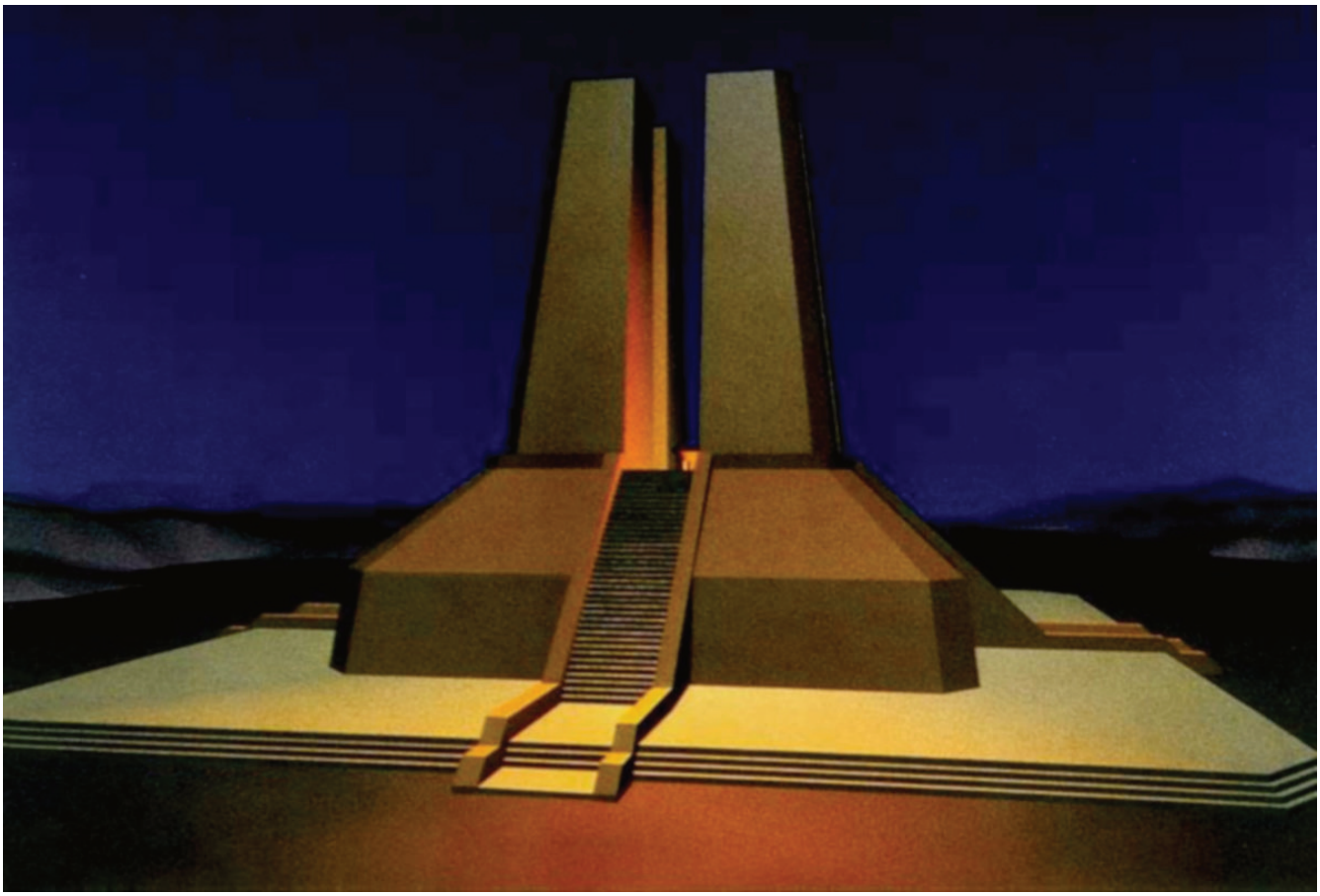


Trees on a golf course

Chapter 6: Commercial Companies

Commercial Companies

After the innovative developments in the various laboratories across the country, several companies were important players in taking the technology out to the private sector, and developed graphics for visual-image hungry advertising, TV and motion pictures.

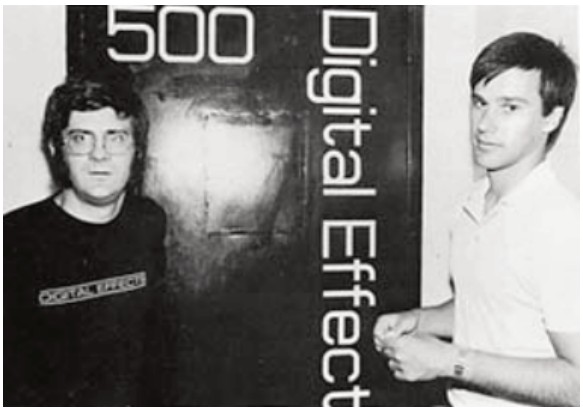


Cray Temple, Digital Productions

6.1 Digital Effects



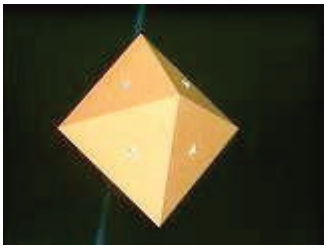
The commercial potential for the evolving computer graphics technologies was obvious to researchers and entrepreneurs alike. First generation companies grew out of the desire to bring synthetic imagery to the television, advertising and film markets.



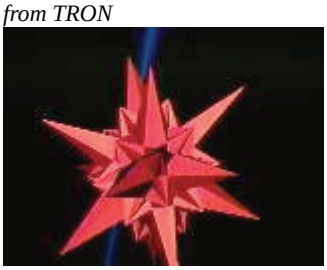
Judson Rosebush (left) and Jeff Kleiser

Founded in NYC in 1978 by **Judson Rosebush**, **Jeff Kleiser** and 5 other partners, Digital Effects was the first CG house in New York, and was one of the first companies to establish itself as a contributor to the film industry in a big way, due in part to the quality of the *Dicomed* **film recorder**. They teamed with Abel, MAGI, and Triple-I to contribute to the motion picture TRON (see Chapter 14 – they did the opening title sequence and the Bit character), but also did national advertisements and television promotions, particularly for CBS and NBC. The company closed in 1986, because of philosophical differences in the way it was to be operated (in the words of Judson Rosebush in the ACM student magazine, "…too many partners.")[1]. Rosebush later started his own company, Judson Rosebush Productions which he founded in 1986, and Jeff Kleiser became a partner in the company called Kleiser/Walzcak Construction, founded in 1987 with his partner Diana Walzcak, to create databases for CGI companies, which they located in Los Angeles and in Massachusetts.

1. DE was founded by Judson Rosebush, Jeff Kleiser, Don Leich, David Cox, Moses Weitzman, Bob Hoffman, and Jan Prins.



The "Yes state" of the Bit character from TRON



The "No state" of the Bit character from TRON

The following quote is from Jeff Kleiser, as published in *CG 101* by Terrence Masson:

> "Our original setup was a 1200-baud modem connection to an Amdahl V6 running APL in Bethesda, Maryland, using a Tektronix display to preview wireframes. (Polygons refreshed at one per second—that's one polygon per second!) The perspective data was written onto 9-track tape and was mounted on an IBM 370/158 to do scan conversion. Another tape was written as hi-con images onto 9-track and was shipped to LA for film recording on a Stromberg Carlson 4020 film recorder. Processed film was sent to NYC where I de-interlaced it onto hi-con (high contrast) film and made a print to separate out the colors and have matte rolls that I could mount on an optical printer to do multiple passes with color filters onto color negative, which was then processed and printed at Technicolor downstairs. Total time to see a color image: 1 week tops."

Equipment included a DEC PDP-11/34, the IBM 4341, a Harris 500 and 800, a proprietary frame buffer, a Mitchell full-color 24 bit camera, and a Dicomed D-48 film recorder[2]. Their software, known as *Visions*, written in the computer codes FORTRAN and APL, was proprietary to the company.

Movie 6.1 Digital Effects 1985 Demo

2. Tom Sito, in his book "Moving Innovation: A History of Computer Animation" quoted DE's Judson Rosebush, recalling how DE obtained their state of the art film recorder." [The $300,000 Dicomed film recorder] had been a gift from a rich Washington-type to his mistress, who had ambitions for a career in media. We sent a truck down for it after I agreed to assume the remaining payments on the machine. Considerably less than the $300,000 it originally came for."



Digital Effects animation showreel from 1985
https://youtube.com/watch?v=Mv78UsrZ07g

Terrence Masson, *CG101*, Published by Digital Fauxtography Inc. (2007)
http://www.cg101.com/cg101.com.html

6.2 MAGI



MAGI (Mathematical Applications Group, Inc) was established in 1966 for the purpose of evaluating nuclear radiation exposure. They developed software based on the concept of ray-casting that could trace radiation from its source to its surroundings. This software, called SynthaVision (marketed by Computer Visuals, Inc.) was adapted for use in CGI by tracing light instead of radiation, making it one of the first systems to implement the later concept of ray-tracing for making images.



Ray Tracing

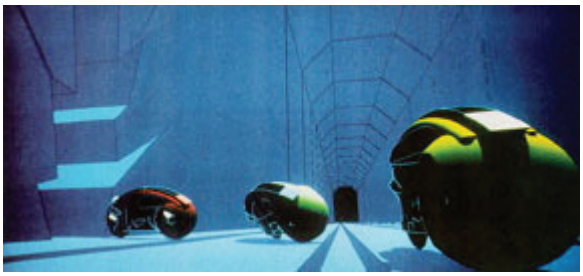
The software was a **solids modeling** system, in that the geometry was solid primitives with combinatorial operators. The combination of the solids modeling and ray tracing (later to become plane firing) made it a very robust system that could generate high quality images. The graphics side of MAGI, called MAGI/SynthaVision was started in 1972 by Robert Goldstein, with Bo Gehring and Larry Elin covering the design and film/TV interests, respectively.

MAGI did an early film test for *Close Encounters of the Third Kind*, which was recorded on a custom film recorder (4000 lines of resolution) made by **Carl Machover**. The first CGI ad is attributed to MAGI – an ad for IBM that flew 3D letters out of an office machine.

Larry Elin produced the company's computer animation from 1977 to 1980, when he was joined by Nancy Hunter and **Chris Wedge**. MAGI later joined with Abel, Triple-I and Digital Effects to create scenes for the movie TRON… although they did the majority of the CGI work (about 15 minutes), their most memorable contribution was the light cycle sequence.[1]

1. The following excerpt about Larry Elin, related to the making of TRON sequences, was taken from an article on the Syracuse University website. "Being thousands of miles away from Disney's California studios was logistically difficult, as Elin had to find ways to send the

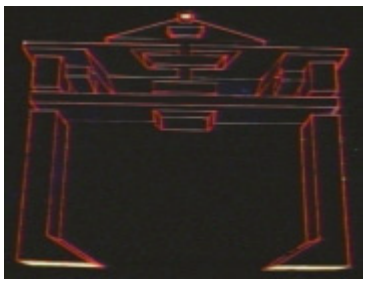
As a result of the TRON account (which totaled approximately $1.2M), more R&D was necessary, so the scientists (including key engineer **Dr. Eugene Troubetskoy**) who had been working on government contracts were brought back to visualization, and MAGI hired Ken Perlin, Gene Miller, Christine Chang and several others. On the production side, they added Tom Bisogno, Tom Miller, and Jan Carlee.



Light Cycles

MAGI's computer imagery occurs mostly in the first half of TRON in the Game Grid area, where they created such vehicles as the Lightcycles, Recognizers and Tanks. As mentioned above, MAGI employed the unique process of computer simulation called SynthaVision. The computer recognized the basic geometric shapes as solid objects with density. By varying the size and quantity of these shapes, MAGI constructed a limited variety of three-dimensional designs which could be easily animated. The SynthaVision process was limited in its ability to create complex objects. It was, however, very easy to create fluid motion (choreography) for these objects. Based on its strengths in motion animation, MAGI was assigned the computer imagery for the first half of the film, which consists mostly of dynamic action sequences.





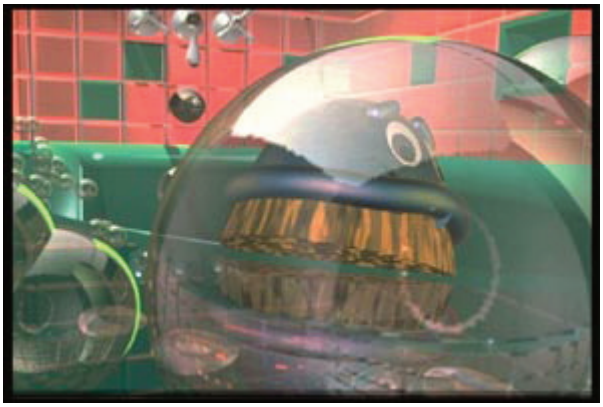
A Celco film recorder was purchased in order to efficiently output in Vistavision. After the movie, they opened an LA office in 1984 in order to capitalize on the success of the motion picture. Phil Mittelman recruited **Richard Taylor**, who supervised the effects for TRON while at Triple-I, to head this office, which closed soon after its establishment. One of the more interesting productions done at MAGI was a test for Disney (*Where the Wild Things Are* – more about the test can be seen in section 2 of Chapter 14) which used 3D scenes and camera

Movie 6.2 Where the Wild Things Are Test

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/wild-things3-1.m4v

control and 2D character animation. This test was supervised by Disney animator **John Lasseter** (now at Pixar). David Brown, who was a marketing executive with CBS/Fox Video and who later co-founded Blue Sky Studios, was brought on to head up the New York sales and production facility.

company's work across the country without the Internet. They had a computerlike machine connected to a telephone that transmitted information at roughly 1,200 bits per second — meaning that an 11-second scene could take an hour to transfer. Often, it made more sense to put the film cans on a plane to Burbank. In either case, Disney never sent anything back, and MAGI didn't get to see what the finished scenes looked like until the film premiered."



Scenes from Dow Scrubbing Bubbles ad



They sold to a Canadian firm, Bidmax, and the personnel dispersed to other companies and universities. In particular, Chris Wedge went to Ohio State before joining with several others to found Blue Sky Productions; Phil Mittelman established the UCLA Lab for Technology and the Arts; Larry Elin went to Syracuse University; Ken Perlin went to NYU and later won an Academy technology award for his **noise functions** in **procedural rendering** (see more about Perlin and his contributions in Chapter 19). (Note: Phil Mittelman passed away in 2000; David Brown passed away in 2003.)

Equipment included a Perkin/Elmer 3240, a Gould SEL 3287 and one of the first Celco film recorders, the Celco CPR 4000. Software was based on **combinatorial geometry** (solid modeling) using raycasting.

Movie 6.3 MAGI Demo – 1980



1980 commercial demo reel from MAGI Synthavision
https://www.youtube.com/watch?v=lAYaX6NuI4M

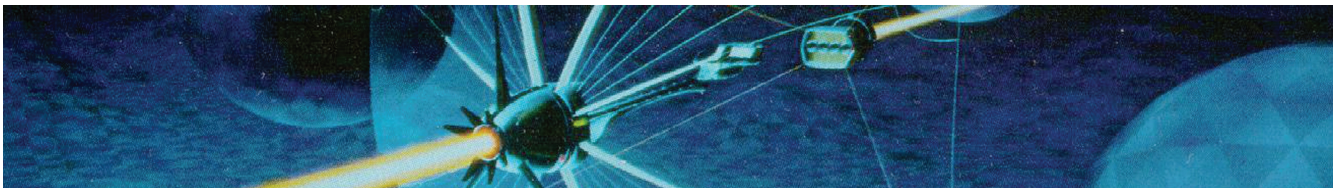
Movie 6.4 MAGI 1982 Demo



1982 commercial demo reel from MAGI Synthavision
https://www.youtube.com/watch?v=WxetroPVCl0

Movie 6.5 MAGI Demo (1984)
*https://www.youtube.com/watch?v=Ivk_LPQP6Ag***Movie 6.6** MAGI First Flight (1984)
https://www.youtube.com/watch?v=EQZO1-4D0lg

6.3 Information International Inc. (III, or Triple-I)



While at Cal Tech, **Gary Demos** was made aware of the work of John Whitney, Sr. who was teaching classes there, experimenting with early CG images. Whitney's work, and that of the University of Utah, prompted Demos in 1972 to go to work for Ivan Sutherland at Evans and Sutherland (see Chapter 13.) E&S used DEC PDP-11 computers along with custom E&S hardware, including the E&S Picture System and a variation of the frame buffer which was used at Utah. At E&S, Demos began discussions about filmmaking with Ivan Sutherland, and together with Glen Fleck and John Whitney Jr. they started a company in LA called the Picture/Design Group. P/DG worked on several film projects, including a test for the Carl Sagan TV show"Cosmos", and some joint projects with Information International, Inc. Founded in 1962, Triple-I was in the business of creating digital scanners and other image processing equipment.



Mercedes logo



Early ABC logo

The Triple-I graphics effort was founded as the Motion Pictures Product Group by Whitney and Demos (with Art Durinski, Tom McMahon, and Karol Brandt soon joining) in 1974. Early software was written by Jim Blinn, Frank Crow, Craig Reynolds, and Larry Malone. Blinn developed software (Tranew) for Triple-I, which ran on a modified DEC PDP-10, called the **Foonly F1**, which came out of the Stanford Research group and was originally used for OCR. They did some early film tests and broadcast graphics work for the European market. Motion picture work included TRON, *Futureworld, Westworld,* and *Looker*. They also produced *Adam Powers, the Juggler* as a demo of their capabilities.

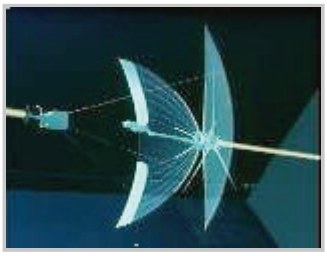
They marketed their services as "Digital Scene Simulation", and did several spots for Mercedes, ABC and KCET, as well as tests for scenes in *Close Encounters of the Third Kind* and an X-wing test for *Star Wars*.

Triple-I hired Richard Taylor, an art director at Robert Abel, to handle the creative director efforts there. He brought a sense of film production to Triple-I, which in his words were lacking. He directed "*Adam Powers*" and was assigned as the effects supervisor for TRON (Triple-I produced the MCP, the Solar Sailor, and Sark's Carrier). Other projects included tests for Disney's *The Black Hole* and the *Empire Strikes Back*, a stereo production called Magic Journeys, and many groundbreaking television advertising and promotion sequences.



Adam Powers – Animation (1981) at https://www.youtube.com/watch?v=GrANBKzcl_8

Although they defined much of the early commercial perception of CGI, concerns regarding the computing power necessary to continue in the business prompted Whitney and Demos to leave to establish Digital Productions in 1981. They departed before TRON was completed, so much of the Triple-I contract was taken up by MAGI. Richard Taylor continued to handle the effects supervision, and was hired by MAGI when the film wrapped.



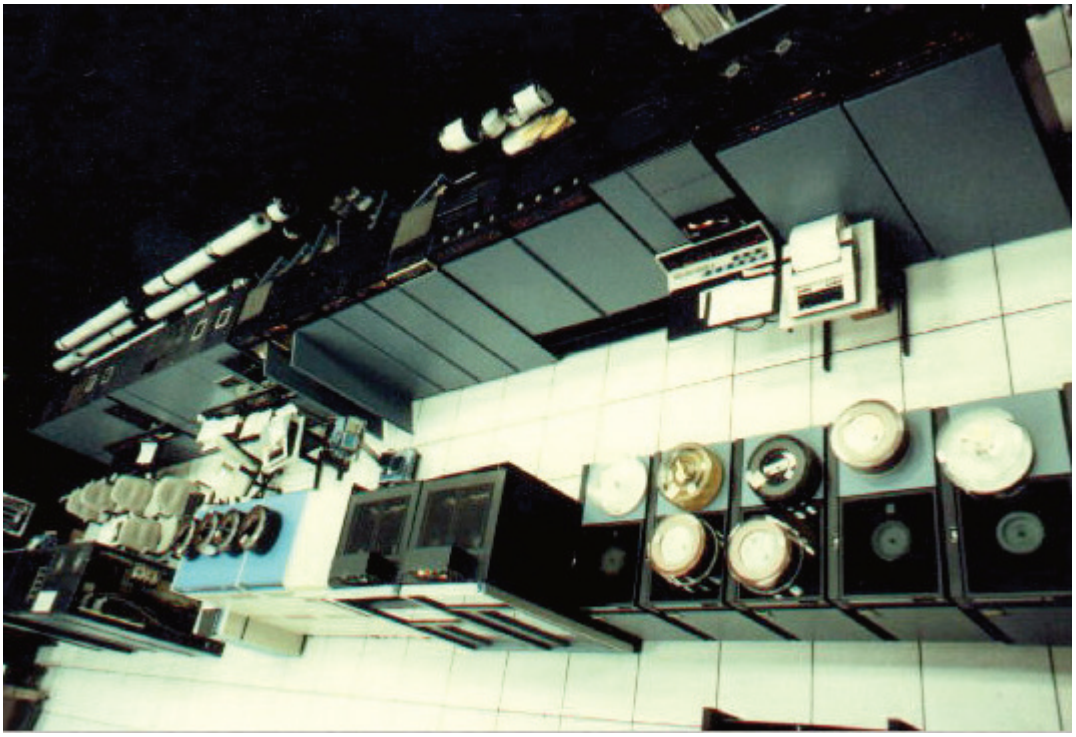
Frames from TRON – Solar Sailor –



MCP



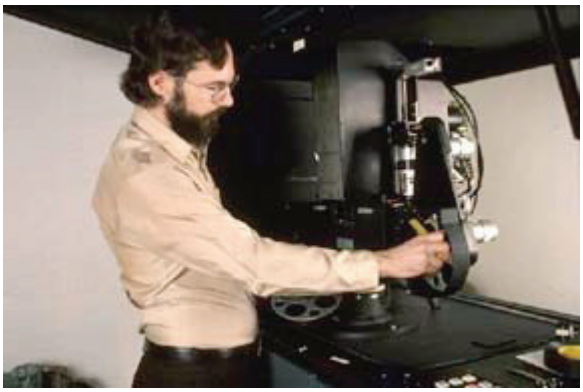
Sark's Carrier



Foonley F1

Equipment at Triple-I included PDP-10s, the famed *Foonley F1*[1], a proprietary 1000 line **frame buffer**, and a proprietary *PFR-80* film recorder. Software included the Tranew rendering package, developed by Jim Blinn, Frank Crow, et al, which ran on the Foonley. Animation was described using ASAS (Actor/Scriptor Animation System) developed by **Craig Reynolds**. Modeling was done on the Tektronix 4014 display using software developed by Larry Malone. The entire production process was labeled **Digital Scene Simulation**, a trade name that carried over to the new Digital Productions production company. (See the *paper* by Demos, Brown and Weinberg.)

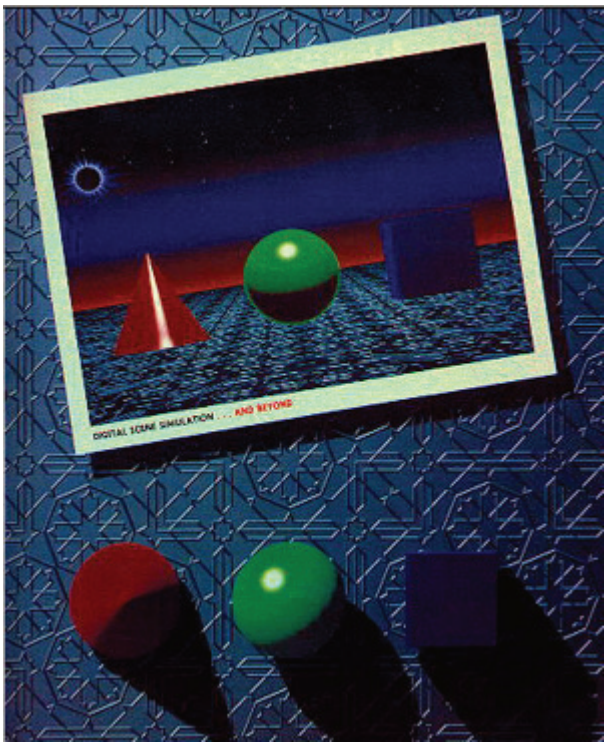
1. *From the recollections of Dave Dyer, no longer available online: "Dave Poole, Phil Petit, and Jack Holloway came to Information International (Triple-I or III)] with a proposal to build an updated version of the original design (using ECL instead of TTL). I'm not quite sure how it came about - pretty crazy idea - but the connections between Triple-i and SAIL were deep and wide in those days. Triple-i was using PDP-10s for OCR, and for their groundbreaking movie group under Gary Demos and John Whitney, Jr. Triple-I had the usual grandiose plans requiring bigger and better computers. The three foonly principals spent about a year designing, constructing, and debugging the F-1. Poole was the mainstay, Petit was around quite a bit, and Holloway appeared only at crucial moments. My impression was that Triple-i paid the costs of construction and very little more - an incredible deal for Triple-i, considering that the F-1 actually worked. It would have been a very expensive boat anchor if it hadn't. I did a lot of work on the software - console computer program, a second version of the microcode assembler, and a port of TOPS-10 to run on foonly itself; and spent many fine hours with Poole, deducing I-Box bugs from errant program behavior. Shortly after the F-1 was operational, Triple-I and I parted ways and I mostly lost track of the F-1. Triple-i got out of the movie biz; the Foonly ended up following Gary Demos to several other early digital effects companies."*



Gary Demos and the PFR-80

For the *FutureWorld production, t*he PFR (programmable film reader) had color film scanning and recording capabilities added. From this basic system, Triple-I developed what would be known as their DFP system (for digital film printer) beginning in 1978. A frame buffer was added, and the film recording and scanning became operational in 1981 after delays in the optical system development.

Gary Demos and John Whitney, Jr. went on to form Digital Productions, and later Whitney/Demos, and Demos then founded DemoGraFX (which was acquired by Dolby Laboratories in 2003), where he worked with digital TV, HDTV standards, **digital compositing**, and other high technology graphics related projects.



Digital Scene Simulation postcard

Whitney founded USAnimation, which later became Virtual Magic Animation, in 1992. Demos and Whitney received the Academy of Motion Picture Arts and Sciences' Scientific and Engineering Award for the Photo Realistic Simulation Of Motion Picture Photography By Means of Computer Generated Images in 1984 for work on the movies "*The Last Starfighter*" and on "*2010*" using the Cray XMP. Demos also received an Academy Scientific and Engineering Award in 1995 for Pioneering Work In Digital Film Scanning", and an Academy Technical Achievement Award in 1996 for Pioneering Work In Digital Film Compositing Systems.

Movie 6.7 Triple-I Demo – excerpt

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/tripli-i-excerpt.m4v

Digital Scene Simulation: The Synergy of Computer Technology and Human Creativity, by Gary Demos, Maxine D. Brown, Richard Weinberg, Proceedings of the IEEE, Volume: 72 , Issue: 1,Jan. 1984

My personal history in the early explorations of computer graphics, by Gary Demos. Visual Computer, Vol 21, 2005.

Symbolics Graphics Division

Marvin Minsky and John McCarthy established the Artificial Intelligence Laboratory at MIT as part of Project MAC in the early 1960s. McCarthy's work included the development of the programming language LISP. In 1965 Minsky hired Russell Noftsker to head the lab. He and a colleague Richard Greenblatt worked together to commercialize Greenblatt's idea of a LISP workstation, and in 1980 he founded Symbolics, Inc. Their first LISP machine, the Symbolics LM-2 was released in 1981, followed soon after by the Symbolics 3600 series, which proved to be an excellent workstation for computer graphics production.



Symbolics 3600 Ad

Shortly after the introduction of the LM-2 workstation, the Triple-I graphics division ceased to operate, and several of the key employees joined Symbolics as the Symbolics Graphics Division.

Included in this group were Tom McMahon, Larry Malone, Craig Reynolds Larry Stein, Matt Elson, Bob Coyne, and others. Out of the southern California shop, the group developed software and hardware built around the LISP architecture. The major contribution to the CGI world was a line of bit-mapped graphics color video interfaces and the very powerful S-Graphics software suite (S-Paint, S-Geometry, S-Dynamics, S-Render) for Symbolics Genera operating system.

The S-Graphics software was used in the production of several notable films, including *Stanley and Stella in: Breaking the Ice* (1987), *The Little Death* (1989), *Ductile Flow*, presented at SIGGRAPH 90, *Jetsons: The Movie* (1990), *Virtually Yours* (1991), and 3D animation of the Orca whale for *Free Willy* (1993).

Symbolics workstations were the first computers capable of processing HDTV quality video, which enjoyed a popular following in Japan. As a result of the capabilities of the computers, Symbolics entered an agreement with a Japanese trading company, Nichimen. The Graphics Division was later sold to Nichimen in the early 1990s, and the S-Graphics software was ported to Franz Allegro Common Lisp on SGI and PC computers running Windows NT. It was later integrated into the Mirai software platform by Izware LLC, and has been used in movies, such as New Line Cinema's *Lord of the Rings*, video games, and military simulations.

The Symbolic's 3600 series computers were also used as the first front end "controller" computers for the Connection Machine massively parallel computers manufactured by Thinking Machines Inc. (see the section on Karl Sims in Chapter 19).

Movie 6.8 The Little Death



Produced on Symbolics, by Matt Elson
https://www.youtube.com/watch?v=rLGRSOfnnUM

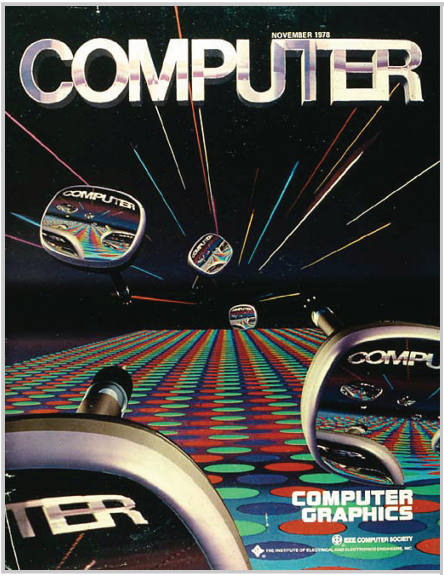
Movie 6.9 Virtually Yours



From The Mind's Eye compilation #7
https://www.youtube.com/watch?v=BdTGJChDKrM

> The Symbolics 3600 with the standard black-and-white monitor made a cameo appearance in the movie *Real Genius*. The company was also referenced in Michael Crichton's novel *Jurassic Park*.

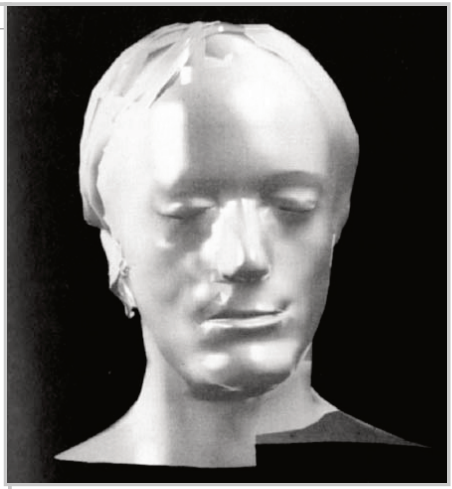
Gallery 6.1 Triple-I Images



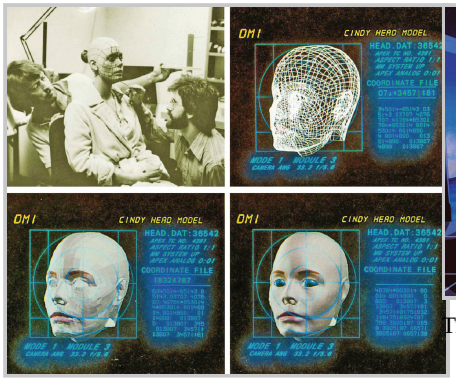
Cover of November 1978 IEEE Computer magazine.



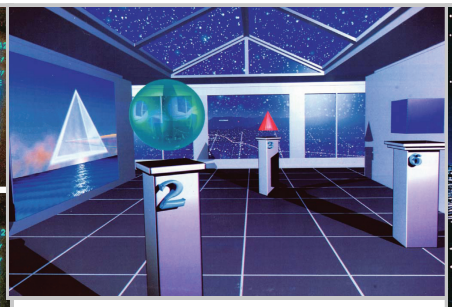
August 1980 cover of Computer Pictures trade magazine



Digitized head of Peter Fonda, for the movie FutureWorld (1976)



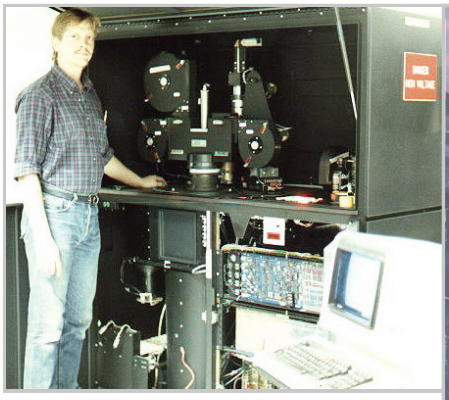
Cindy's head from the movie Looker (1980). Actress Susan Dey is digitized from reference lines by Art Durinski and Larry Malone.



Triple-I Museum (1979)



Color fringing adds to visual realism (1978)

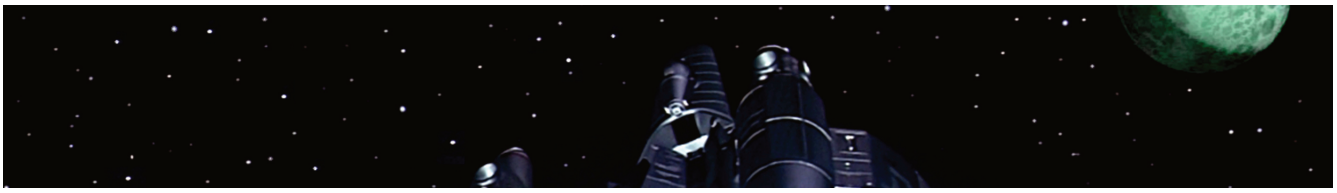


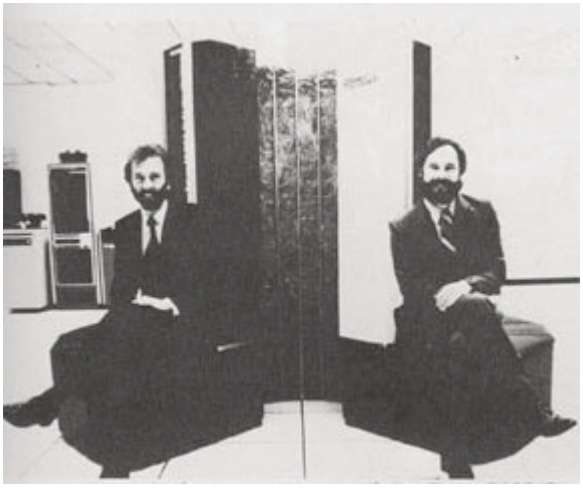
David Keller is shown here with the Digital Film Printer, developed by Gary Demos while at Triple-I.



Cover of the August, 1979 IEEE Computer Magazine. Gary Demos produced this X-wing fighter image to convince George Lucas that CG could be used to make images for Star Wars.

6.4 Digital Productions (DP)





Gary Demos and John Whitney, Jr. sitting at the Cray computer

Digital Productions was started by John Whitney, Jr. and **Gary Demos** in 1981, after they left Triple-I because of a disagreement over the amount of computing power that needed to be devoted to feature film production, particularly for the movie TRON. DP was financed by Control Data Corporation, and the Cray 1S was leased from Ramtek, the frame buffer company.

Their ultimate goal was to emphasize “high scene complexity and computational efficiency” with a focus on “large scale simulated special effects production”, particularly for the motion picture industry. Key employees in the company were Elsa Granville (HR), Larry Yaeger (VP of Software), Craig Upson, Steve Williams, David Ruhoff, Jim Rygiel, Brad Degraf (Head of Production), Producers Nancy St. John and Sherry McKenna, Jim Rapley, Art Durinski, and others. At their peak, DP employed between 75 and 100 employees, and executed special effects for a number of films and advertisements.

Although the Cray provided DP with the computing power that Whitney/Demos desired, it was at a great price… one trade publication indicated that in addition to the cost of the lease, it required approximately $12,000 per month for electricity, and approximately $50,000 in maintenance. Many in the industry claimed that this kind of expense could not be justified by the kinds of contracts that existed in the effects industry at the time, but Whitney and Demos persisted.

Some of the more notable projects include 250 scenes and 27 minutes of CGI for summer 1984's *The Last Starfighter* (which cost $14M – DP's contract was for $4.5M – and grossed only $21M), Mick Jagger's Hard Woman music video, *Labyrinth*, and the Jupiter sequence for *2010*, the sequel to 2001. DP also worked on some fairly famous and notable ads and TV promotions, including AT&T (with designer Saul Bass), Pontiac, Mercedes-Benz, the Chevrolet Astro Van, and STP. **Brad DeGraf** created a connection for "Waldo" (from a sci-fi book by Robert Heinlein in the 40s), the digital puppet used by Henson Productions, to integrate motion activities in a real time sense (some argue that this was the birth of motion capture). Keeping the *Digital Scene Simulation* process developed at Triple-I, they expanded the software to take advantage of the supercomputer architecture.



Gunstar



Cray XMP Supercomputer

Equipment included E&S Picture Systems used for modeling, IMI vector graphics displays for defining and pre-visualizing the animation, and the Ramtek framebuffers used for raster display. Images were calculated and filmed at 2000×2560, and were recorded on the modified PFR at speeds that could reach 12 seconds per image, due to a fast interface to the Cray (note: the Cray 1S was replaced by the Cray XMP in 1983.). Some excess Cray cycles were sold to companies such as General Motors and Ford Motor for their own use.

In late 1984 or early 1985, the expenses of running the company, including the high cost of running the Cray, resulted in the need to discontinue the lease on the Cray, and DP was forced to purchase it outright for $17M. Later in 1985, CDC and Ramtek were both suffering financial woes, and they began to look for ways to get out of the movie making business.

In June of 1986, they agreed to terms, and DP was bought in a hostile takeover by Omnibus Computer Graphics from Canada. Whitney and Demos sued Ramtek for part of the sale proceeds, and were subsequently locked out of their offices in July and a counter suit was filed alleging that W/D started a competing company (Whitney/Demos Productions) and hired away employees. Omnibus changed the Digital Scene Simulation concept to Omnibus Simulation. They also took over Able and Associates that year, and the entire venture fell apart in 1987. (See the discussion in the Omnibus coverage below.)

Whitney/Demos Productions

Demos and Whitney, Jr. started Whitney/Demos Productions after the Omnibus takeover in 1986. They built the company around the Thinking Machine CM-2 and Symbolics workstations. Programming was done in LISP. One of the premiere pieces that was produced was the movie Stanley and Stella: Breaking the Ice ,

produced with Craig Reynolds of Symbolics, Philippe Bergeron and others. Key employees included Karl Sims, Karol Brandt, Michael Whitney, Mary Ann Morris, David Ruhoff and others. They also had a T.V contract for promotional material for CBS. In 1988 Whitney reorganized the company into USAnimation and Demos founded DemoGraFX.



DemoGraFX President, Gary Demos accepting his 1995 Academy of Motion Picture Arts And Sciences Engineering Award for his pioneering work in digital film scanning.

Gary Demos accepts 1995 Oscar for the development of the PFR

In 1985, Gary Demos received his first Scientific and Engineering Award by the Academy for Motion Pictures Arts and Sciences (with John Whitney, Jr.) for the practical simulation of motion picture photography by means of computer-generated images (1984 work). In 1995, Demos was awarded his second Scientific and Engineering Award (with Dan Cameron, David DiFrancesco, Gary Starkweather and Scott Squires) for his groundbreaking work in the field of film input scanning. In 1996, the Academy honored him with a Technical Achievement Award (with David Ruhoff, Dan Cameron and Michelle Feraud) for efforts in the creation of the Digital Productions Digital Film Compositing System (the famed DFP). In 2006, Demos was awarded the Gordon E. Sawyer Award, "presented to an individual in the motion picture industry whose technological contributions have brought credit to the industry."

From the DP page of the *People Behind the Pixels: History of Computer Graphics* website:

> "DP's first major computer graphic project was for The Last Starfighter, $4.5 million worth of state-of-the-art high resolution CG animation. Beginning in Oct 83, Digital Productions traded in the 'older'? Cray-1S for the very first Cray X-MP supercomputer.
>
> The Cray was fronted by a VAX 11/780 and was used to produce nearly 300 shots totaling 25 minutes of screen time. The team used E&S PS400's for modeling and IMI vector motion systems for motion preview with Ramtek frame buffers for display. When Triple-I had wrapped the TRON work and decided not to continue in the CG film business, DP leased the Digital Film Printer (DFP) and hooked it up to on of the high speed channels of the Cray. The Cray driven DFP could scan 35mm film at four seconds a frame, and film out the 2000×2560 rendered images at twelve seconds a frame.
>
> For the first time, highly detailed computer generated images were integrated with live action as realistic scene elements, rather than as monitor graphics or deliberately 'CG' looking images. Gary Demos from the very beginning always had the drive to only produce the highest resolution, highest quality imagery possible. Kevin Rafferty(ILM) led the team that digitally encoded (modeled) many of the forms designed for the film by Ron Cobb. The technique used was to have top, front and side views of the model drawn orthographically on blueprint-like paper. A mouse/cursor (or puck?) with cross hairs would then be used to input the lines of the drawing, one point at a time. Details even included little 3D digital stunt actors inside the Gunstar cockpit."

My personal history in the early explorations of computer graphics, by Gary Demos. Visual Computer, Vol 21, 2005.



1984 Ad from Computer Pictures Magazine

Movie 6.10

1984 Demo Reel

Movie 6.11

Humantech Ad (1986)

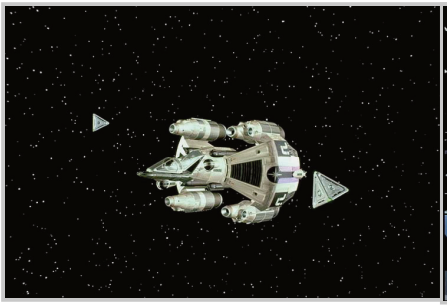
Movie 6.12

Scenes from The Last Starfighter

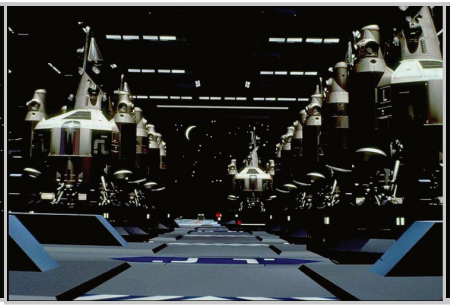
Movie 6.13

Mick Jagger's Hard Woman – 1985

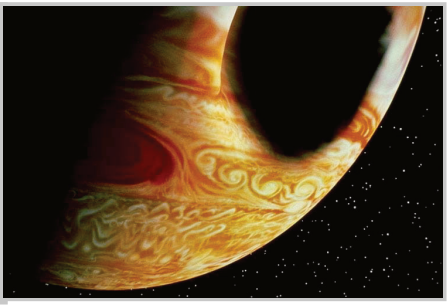
Gallery 6.2 Digital Productions Image Collection



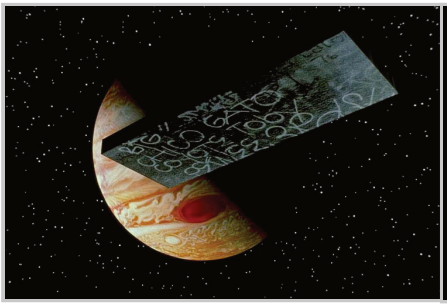
?X-wing fighter from The Last Starfighter



?Scene from The Last Starfighter



Scene from the Jupiter sequence from the movie 2010



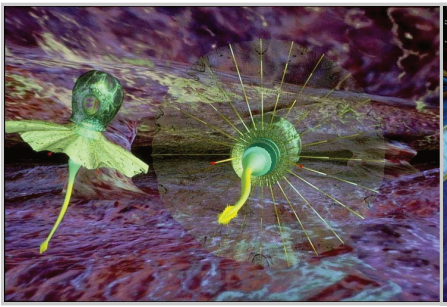
Scene from the Jupiter sequence from the movie 2010

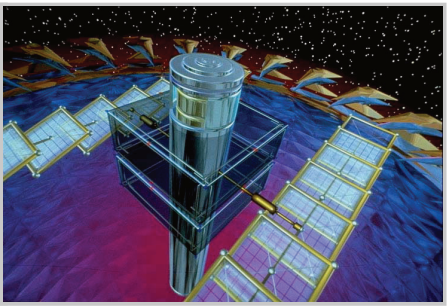


Scene from Labyrinth



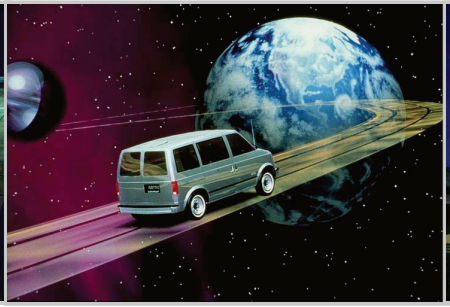
Scene from Hard Woman music video



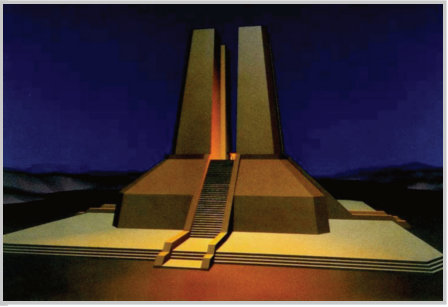




Scene from Pontiac commercial



Scene from Dodge commercial



Cray Temple, Digital Productions

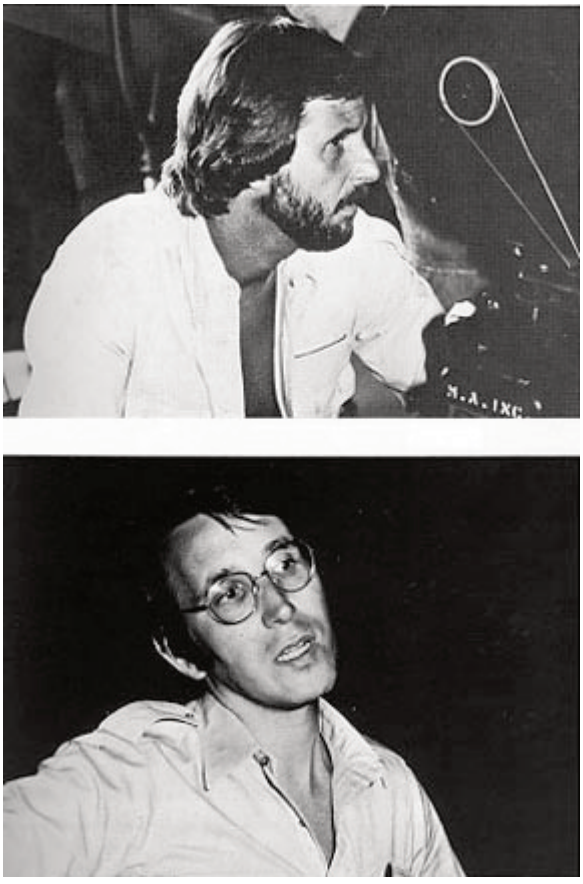




Texture mask tests

6.5 Robert Abel and Associates





Bob Abel (top) and Bill Kovacs

Robert Abel & Associates was founded in 1971 by Bob Abel, with his friend and collaborator Con Pederson. Abel had done early film work with famous designer **Saul Bass** and camera work with John Whitney, who was working with Bass on titles for Hitchcock's *Vertigo*. After touring with several rock bands documenting their concerts, Abel joined Pederson to adapt the camera system used for the movie *2001* to general film effects work, particularly for the ABC television network, in conjunction with **Harry Marks**. ?Early expertise was in multiple stop motion photography rigs and special film effects layouts. At one point Abel & Associates employed nine horizontal motion control tracks, several 360 degree motion-controlled boom arms, **optical printers**, front and rear projection systems, and vector and raster graphics systems.

Abel did early innovative work in film effects, including creative use of **slit-scan** and film streaking, including a process perfected by Richard Taylor that was dubbed the "candy-apple neon" look used in famous spots for 7-Up and Levis.



Scene from 7-Up commercial

The company later developed sophisticated pre-visualization vector graphics tools, using the Evans and Sutherland (E&S) PS2 graphics display. **Bill Kovacs** pushed this technology further, and created some outstanding graphics filmed directly from the vector device using vector fill approaches, including the notable Panasonic Glider animation, ads for TRW, and the The Black Hole test for Disney, which was used for the opening sequence of the movie.

Originally used in static photography to achieve blurriness or streakiness, ***slit-scan*** was perfected for the creation of spectacular animations. It enables the cinematographer to create a psychedelic flow of colors. It was adapted for film by Douglas Trumbull during the production of Stanley Kubrick's *2001: A Space Odyssey* and used extensively in the "stargate" sequence.



Slit-scan is an animation created image by image. Its principle is based upon the camera's relative movement in relation to a light source, combined with a long exposure time. The process is as follows:

1. An abstract colored design is painted on a transparent support

2. This support is set down on the glass of a backlighting table and covered with an opaque masking into which one or more slits have been carved.

3. The camera (placed high on top of a vertical ramp and de-centered in relation to the light slits) takes a single photograph while moving down the ramp. The result: at the top of the ramp, when it is far away, the camera takes a rather precise picture of the light slit. This image gets progressively bigger and eventually shifts itself out of the frame. This produces a light trail, which meets up with the edge of the screen.

4. These steps are repeated for each image, lightly peeling back the masking, which at the same time produces variation in colors as well as variation of the position of the light stream, thus creating the animation.

(From *http://www.rtbot.net/Slit-scan*)

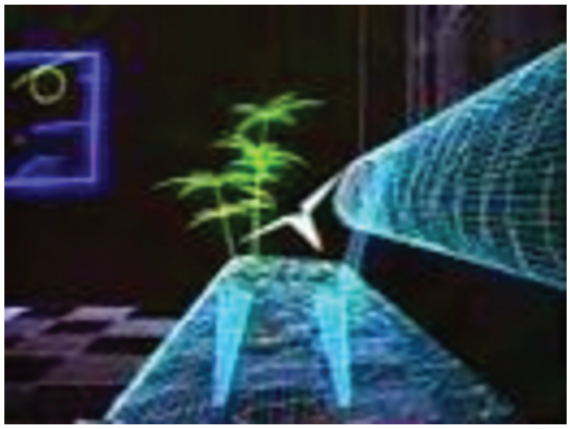
A good example of a slit-scan production is this opening for ABC television at https://www.youtube.com/watch?v=rM-Vkd7On2Q



Employees of Robert Abel and Associates (Abel is in row 3 in the center)

Abel was one of four companies (with Triple-I, Digital Effects and MAGI) contracted to do graphics for the Disney movie TRON in 1982, after Disney worked with Abel for promotional materials and The Black Hole project.

Movie 6.14 Panasonic Glider



Produced by Abel in 1981, the animation was filmed directly from the screen of the E&S vector display, using colored filters https://www.youtube.com/watch?v=3KFV0HbYULk



Scene from Brilliance

Abel later got heavy into raster graphics with software developed by Bill Kovacs, Roy Hall, Kim Shelly, Michael Wahrman, and others through a division called Abel Image Research. Key Abel raster work included a short demo film entitled *High Fidelity*, ads for Benson and Hedges, the *Sexy Robot* (after Fritz Lang's 1926 robot in Metropolis?), a now-famous ad titled *Brilliance*, and the opening sequence for Spielberg's *Amazing Stories* television show (*see 1985 demo reel*.)

Abel garnered multiple Clio awards (33) and had arguably the finest collection of art and technical directors in the industry. Their strength was in the ability to bring the knowledge of traditional effects work, cinematography and film making to the area of CGI. The list included "Doc" Baily, Michael Gibson, Frank Vitz, Tim McGovern, Randy Roberts, Charlie Gibson, Dale Herigstad, Richard Hollander, John Hughes, Steve Goldberg, Kenny Mirman, and others.



Robert Abel? – Image source: Animation World Magazine

Abel Image Research, or AIR, as it was known in the discipline, was established as a subsidiary of Abel and Associates, and was charged with developing and licensing raster software for production. Their success was limited, and the division was ultimately purchased for $1M by Wavefront, ostensibly to keep AIR from competing with the new software company.

Besides the stable of motion control and film equipment, computer graphics equipment included DEC Vax, Gould and SGI computers, Evans & Sutherland vector devices, Raster Tech frame buffers and proprietary film and recording equipment.

Some people suggest that the Abel raster software was later developed into the Wavefront Technologies product when Bill Kovacs purchased the rights to it in 1987; others dispute this, and maintain that Wavefront was developed independently, with obvious influence from the Abel software only. Abel was acquired in October, 1986 by John Pennie of Omnibus Computer Graphics of Canada for $7.3 million.

Movie 6.15 Excerpt from *High Fidelity*

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/hi-fi.m4v

High Fidelity, a 1982 animation by Robert Abel and Associates to demonstrate the 3D raster capabilities of Abel Image Research (produced by Abel and Randy Roberts)

In 1987, Omnibus defaulted on investments and closed DP, Omnibus and Abel on March 27, 1987 (called DOA day). As a result of the closure, many former Abel animators and directors left and were instrumental in starting or working for other high quality CGI companies, including Rhythm and Hues, Metrolight, Sony Imageworks, Santa Barbara Studios, Boss Films, Kroyer Films, deGraf/Wahrmann, etc. Abel went on to be an Apple Fellow, and started his own company, Synapse Technologies, and began producing two interactive multimedia projects for IBM, “Evolution” and “Revolution,” as well as a project about flight for the Smithsonian Air and Space Museum. He also was affiliated with the Center for the Digital Arts at UCLA. (Note: Bob Abel passed away in September 2001.)



Ad for Abel from 1984 Computer Pictures magazine

Movie 6.16 Robert Abel and Associates AT&T ad (1980)

http://www.youtube.com/watch?v=IrnUdM_uF7s

Movie 6.17 Robert Abel and Associates Demo (1981)

http://www.youtube.com/watch?v=QwpOSZeGmzw

Movie 6.18 Robert Abel and Associates Demo (1982)

http://www.youtube.com/watch?v=cT3_3d2JcR0

Movie 6.19 Robert Abel and Associates Demo Reel (1985)

http://www.youtube.com/watch?v=-1Yozk0g1YM

Movie 6.20 Robert Abel and Associates *7up Bubbles* commercial

http://www.youtube.com/watch?v=K2U-lP-SOSQ

Movie 6.21 Robert Abel and Associates *Hawaiian Punch* ad (1987)

featuring music by Mark Mothersbaugh of *DEVO*

http://www.youtube.com/watch?v=SIfh0XMrg6w

Movie 6.22 Robert Abel and Associates *Benson and Hedges* ad (1987)

http://www.youtube.com/watch?v=fdBoKOpctp4

Movie 6.23 Robert Abel and Associates *Brilliance* ad (1983)

http://www.youtube.com/watch?v=sCXYxNt02RI

Movie 6.24 The Making of Brilliance

http://www.youtube.com/watch?v=eedXpclrKCc

Movie 6.25 High Fidelity
https://www.youtube.com/watch?v=WFoRJ5w2eEM

The February 2005 tribute by Ellen Wolff in VFXWorld magazine titled
Honoring Bob Abel: VES Bestows First George Méliés Pioneer Award
published before his posthumous Visual Effects Society honor.

> "To accomplish his goals, Abel nurtured a new generation of artists to create the studio's string of award-winning CG spots. Kenny Mirman, who had worked on *Tron*, directed a series of innovative commercials for clients like TRW and Benson & Hedges. Mirman has likened Abel to Jedi master Obi-wan Kenobi, for the way he mentored the talent at RA&A. Bob believed "one of the things that makes us special is that we pool people's talents," and RA&A paired art and technical directors together in highly productive ways."

Excerpt from a Eulogy to Robert Abel by Kenny Mirman

Given at his Memorial Service on September 25, 2001
Read in its entirety at *https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/05/VFXPro-Abel-.pdf*

Bob's beloved family Marah and Josh, Judi, Jerry and Kirsten, and to Bob's dear friends, colleagues, students… DREAMERS.
We've lost the man carrying the torch.
The Navigator.
The one who lit the way.
Sometimes by wildfire.
Sometimes by light alone.
Sometimes by the seat of his pants.
It was Faith.

This Visionary, he was in the front, always, and his torch treated us to a view of remarkable beauty, wisdom and truth. He showed us the way, and it was magic.
Bob Abel endeared us, gifted us, inspired us, blessed us, revived us, guided us, to BE something we never thought possible…
True to our hearts.
Bob inspired us to not only dream, but to make our dreams reality. And he taught us by example of his passionate life. It borders on incomprehensible how Bob Abel, this man of such unspeakably passionate creative vitality and wisdom, could be taken from us so swiftly and so soon. It's an indescribable loss. Yet I have to believe it's some kind of mysterious beauty. Life's way of perfection. And so I celebrate Bob Abel's life today… this True Artist of a human being.

The one carving the path.
The Maverick. The Rebel. The Inspirer! The MythMaker. The Huckster.
The Storyteller. The Humanitarian. The Gunslinger. The Pitchman.
The Comedian. The Filmmaker. The TEACHER. The Godfather.

There are many more on your own list, I'm sure of it.

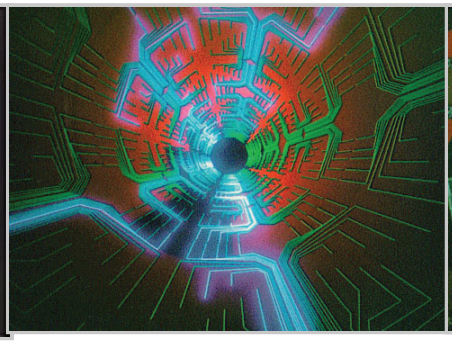
But one thing is certain. I bet that on all of our personal lists of "Who he was," in capital letters it says… Bob Abel was THE VISIONARY.

A guiding light to not only an industry, but to art, to education, and to history.
He moved us. And I miss him deeply.

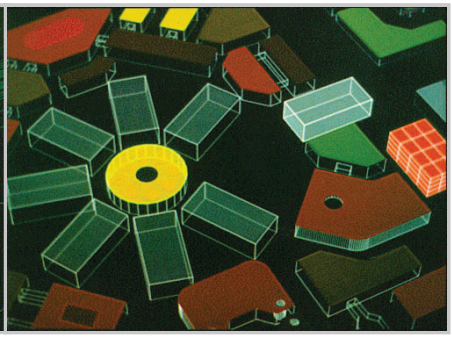
Gallery 6.3 Robert Abel & Associates Image Collection



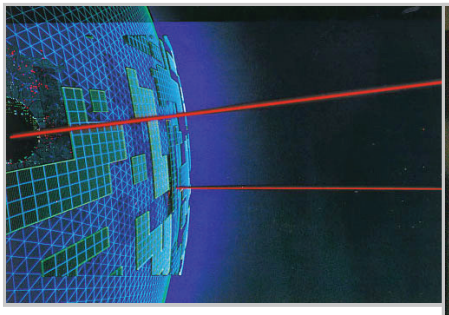
Abel logo



Vector animation from commercial for AT&T



Vector animation from commercial for AT&T



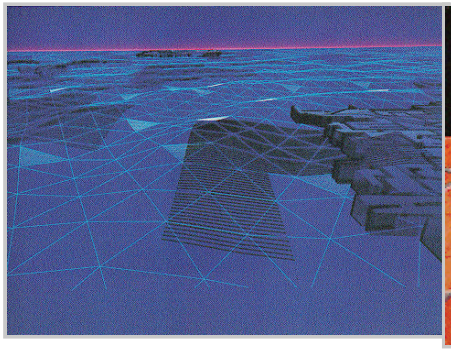
Vector animation from ad modeled after the opening for TRON



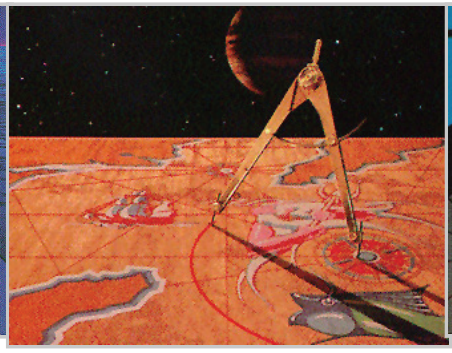
Ad for Philips



Ad for Philips



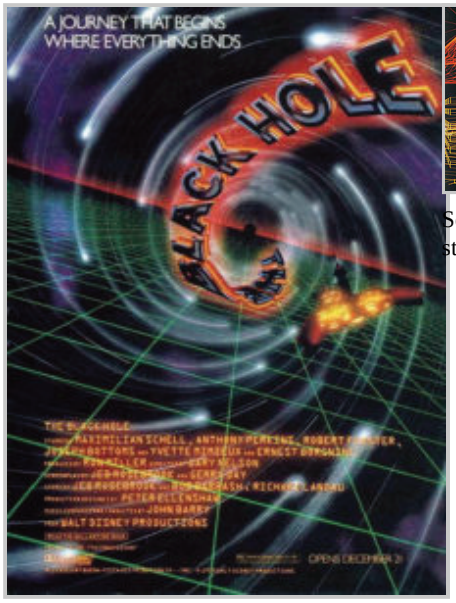
Scene from TRON



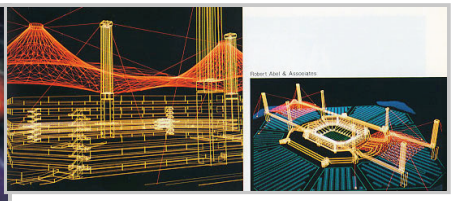
Scene from TRW ad



Scene from animation High Fidelity



Poster for Black Hole



Scenes from a promotional spot for a regional stadium with a movable roof structure

6.6 Cranston/Csuri Productions



In 1981, Charles Csuri approached an investor (Robert Kanuth of The Cranston Companies) to transfer the computer animation technology created in the CGRG lab at Ohio State to the commercial world, and Cranston/Csuri Productions, Inc. (C/CP) was formed.



Cranston Building, home of CCP and CGRG

It moved, along with CGRG to a Columbus facility, the former Academy for Contemporary Problems building, at 1501 Neil Avenue in Columbus. This co-location of the two organizations was important to the continuing development of each. Kanuth appointed one of his officers at The Cranston Companies, **Jim Kristoff**, as President of C/CP, and he recruited six of the CGRG researchers to join the company as a core group.

These six C/CP staff (Michael Collery, Wayne Carlson, Bob Marshall, Don Stredney, Ed Tripp, and Marc Howard) rewrote the software that was in the research lab so that it was more user-friendly and less research oriented, and added specialized utilities for character animation, procedural effects, rendering, geometric modeling and **post production**. They also expanded the capabilities of the hardware, including their proprietary frame buffers to provide tools for the growing animation staff.



C/CP animators working at framebuffers



ABC News promotion graphic – 1982

The suite of software was used to produce animation for television and advertising until C/CP went out of business in late 1987. During the tech transfer first year, Carlson reworked the modeling program DG, Julian Gomez rewrote the animation language Twixt for use at C/CP, and Stredney and Collery produced a sequence of animations that were edited together into a preliminary demonstration reel to take to potential clients. One of the first major clients was ABC News – C/CP was contracted to produce promotional graphics and openings for all 11 of the network news programs.

The strengths of C/CP were high quality image making hardware and software that was focused on the limited markets they chose to serve (television broadcast and promotion, advertising, and medical documentaries.) Production included a market-appropriate direct-to-video solution that made the production process very efficient. Exceptional sales efforts started with Kristoff and Mark Del Col, and later Scott Haines from Disney and Dobbie Schiff. They also had an effective design staff, headed by Paul Sidlo (Rezn8), that included Steve Martino, John Weber, Ronnie Chang and others.



Video technician Bob Lyon working at Ampex 1” recorder

Special purpose hardware included the Marc III and Marc IV custom frame buffers, which were designed and built by C/CP employee Marc Howard. These frame buffers provided the ability to do extended low resolution pre-visualization motion tests that were stored in frame buffer memory and played back in real time. C/CP used Vax 11/750s, 11/780s, Pyramid computers, Sun workstations, Megatek, IMI and E&S Picture Systems vector displays, and a modified Ampex Electronic Still Store (ESS), which was originally designed for slow motion replay by the television network sports industry[1] The preparation, storage, retrieval, and broadcasting of stills (slides and graphics) add up to a significant cost element that must be controlled in the operation of a typical television facility. The physical handling in using stills can damage the materials and result in human error. Furthermore, reserving a studio camera and/or a telecine chain to show stills is inefficient and not cost-effective. A new system to overcome these problems, the Electronic Still Store (ESS), has now been demonstrated by CBS and Ampex. The ESS can randomly search an electronic library of still pictures from a number of locations, arrange the stills in the order for playing, play them as fast as 1 still/s, and do these things without physically touching the media. The system

1. Originally introduced in 1977 for use by CBS Sports, Ampex was awarded an Emmy for the technology. An article from the SMPTE Journal stated: "

makes available a current stock of about 1500 stills (those expected to be needed within the next 100 days) and a long-term stock of about 5000 stills. System control tasks are handled by an LSI-11 microcomputer which emulates the larger PDP-11/40. The core element of the ESS is a very reliable computer disc drive. The adaptation of the disc drive for storing PCM video requires only that the dissimilar standards of digitally encoded video and the computer peripheral be reconciled." Published in: SMPTE Journal (Volume: 85, Issue: 8, Aug. 1976). Images were calculated and stored on one of several magnetic disks; the machine was programmable to facilitate the 30fps playback with a direct NTSC video output. C/CP also had a Celco 4000 film recorder, which could be used for 16mm, 35mm and 70mm motion picture film, or 35mm slide or 4×5 transparency still output.



Celco 4000 Control Panel

During the seven year period that they were in business, C/CP produced almost 800 animation projects for over 400 clients world-wide. A long-standing relationship with Roger Goodman of ABC resulted in continuous contracts for the production of graphics for ABC Sports for many years.

Key projects included: opening graphics for 3 Super Bowls; the on-air sports promotions for ABC, CBS, NBC, and ESPN networks; news opens and promos for all of ABC's news shows, as well as news opens for CBS, CBN, Fox and PBS; international network promos for ARD (Germany) CBC (Canada) ABC (Australia), Globo (Brazil) and Scottish Television; entertainment graphics for ABC, NBC, CBS, Turner, Showtime, HBO, Fox, and over 100 local affiliates; award winning ads for TRW, Sony, Proctor and Gamble, AEP, G.E., and Dow; music videos for Krokus, Twisted Sister and Chaka Khan; special projects for Goldcrest Films (The Body Machine), CoMap and the Annenberg Foundation (VISUmap animations for "For All Practical Purposes" mathematics telecourse.)

During this period, C/CP staff continued to extend the research boundaries and publish new and innovative results. Former staff members included Shaun Ho (SGI), Michael Collery (PDI), Scott Dyer (Nelvana), Jeff Light (ILM), John Berton (ILM), Susan Van Baerle (Windlight), Maria Palazzi (ACCAD), Doug Kingsbury (Lamb and Co.), John Donkin (Blue Sky), Peter Carswell (OSC), Paul Sidlo (RezN8), Jim Kristoff and Dobbie Schiff (Metrolight), Rick McKee (SGI), Jean Cunningham (PDI), John Townley and Steve Martino (click3west), Tom Longtin and many others.

In 1985 C/CP licensed their production software to Japan Computer Graphics Laboratory (JCGL) for use in the Japanese market. JCGL's president was Japanese businessman Mitsuro (Mits) Kaneko, who later became friends with Jim Kristoff.

The relationship between Kristoff and the board of C/CP cooled in late 1986 and early 1987, primarily because of Kristoff's position that an office needed to be opened in L.A. that would allow C/CP to expand into other markets. In fact, a number of former Abel employees, including Tim McGovern, Con Pederson, Neil Eskuri and "Doc" Baily, were hired and relocated to Columbus for training, ostensibly to prepare to staff an L.A. office. Kaneko and Kristoff proposed an investment strategy that would increase their control, but the funding was not available.

Kristoff resigned, and later opened Metrolight (originally to be called Northern Lights Productions) in L.A. and Wayne Carlson was named President, as Chuck Csuri had left C/CP in 1985 to return to his OSU duties at CGRG. Carlson saw the company through Chapter 11 liquidation (the software was purchased by Lamb and Company in Minneapolis), and Cranston/Csuri formally closed in October, 1987.

Movie 6.25 Gears – NCGA Demo

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/CCP_NCGAGears-1.m4v

Created by Tom Longtin

Movie 6.26 C/CP Demo (1982)
http://www.youtube.com/watch?v=ghNjMCHyu5w

Movie 6.27 C/CP Demo (1983)
http://www.youtube.com/watch?v=6EOFjHbiVMY

Movie 6.28 C/CP Demo (1985)
http://www.youtube.com/watch?v=Q8TYobTi234

Movie 6.29 Clio Finalist Ad for TRW (1986)
http://www.youtube.com/watch?v=GvICw-8WaGk

Movie 6.30 C/CP Ads Reel
http://www.youtube.com/watch?v=8CVkBZJ_zpI

Cranston/Csuri Productions produced over 800 animations for over 400 clients worldwide. Every major television network, including ABC, CBS, NBC, the Canadian Broadcasting Co., German ARD Television, ABC Australia, Rede Globo in Brazil, and the BBC had show openings or promotions produced at C/CP.

Cable networks, including HBO, Cinemax, The Turner Broadcasting Network, TNN, the Country Music Channel, CNN and others did the same.

Sports broadcasts were a specialty, and C/CP produced graphics and animation for CBS Sports, ABC Sports, NBC Sports, ESPN, the NFL, NFL Films, HBO and others. C/CP produced the opening for two Super Bowls, the NCAA Basketball Championships, Major League Baseball, the Breeder's Cup, Wimbledon, College Football and Basketball, and IROC Racing.

All of the major news shows used C/CP graphics, including NBC Nightly News, ABC World News Tonight, and CBS Evening News. ABC contracted for all 11 of their major news shows, and also for the United Airlines in-flight broadcast.

Advertisements included Clio nominated TRW pieces, ads for Sony, IBM, Ameritech, McDonnel Douglas, Jeep, Contac Cold Capsules, Actifed, General Electric, Pert Plus, Procter and Gamble, Always overnight pads, M&I Banks, Benjamin Moore Paints, Lowenbrau Beer, Warner Cable, and many others.

Corporate communications were done for GE, IBM, American Electric Power, Mount Carmel Health, Landor and Associates, Cranston Securities, Cranston Development, and others.

C/CP also specialized in medical animation, producing dozens of sequences for the BBC series The Body Machine. They produced over 40 segments for the Annenberg series on Mathematics for PBS. The produced a generic promotional package for local television markets, customizing it for almost 100 local stations.

They did scene tests for several motion pictures, including an unnamed movie from Disney, Flight of the Navigator,and the Brave Little Toaster.

For a complete list of the C/CP clients, go to *https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/05/CCPClients.pdf*

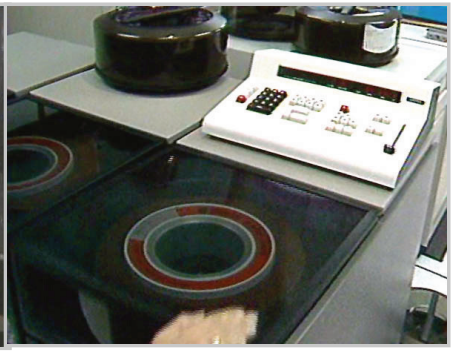
Gallery 6.4 Cranston/Csuri Productions Image Collection



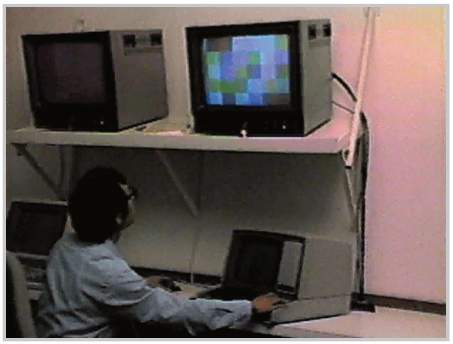
Interior lobby of the Cranston/Csuri headquarters in Columbus



Bob Lyon editing on the Ampex 1" recorders.



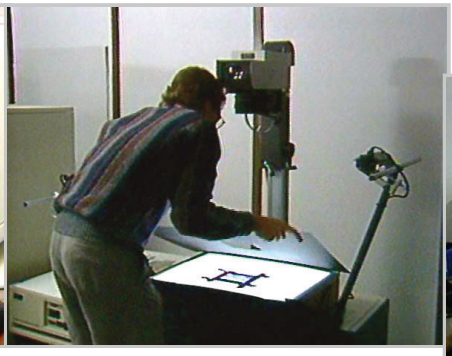
The CCP Ampex Electronic Still Store (ESS)



Hsuen Chung Ho working on the video playback software.



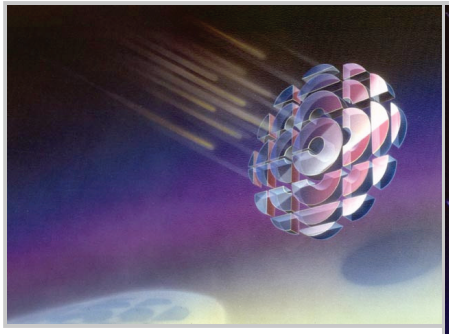
Maria Palazzi at the IMI500 Display



Steve Martino at the film capture station.



Steve Martino at the digitizing table with the Megatek display



Drawing for design of Canadian Broadcasting (produced by Bo Gehring)



ABC Fall promotion



NBC Fall Campaign



NBC Winter Olympics Show promotional graphics



Good Morning America Show Open



PM Magazine show open



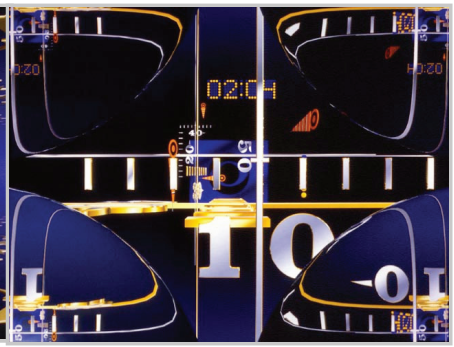
Cinemax show open



CBS Evening News Show Open



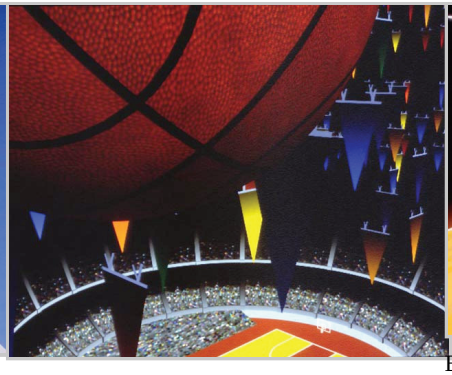
CBS Sports NFL promotion



Superbowl opening graphics



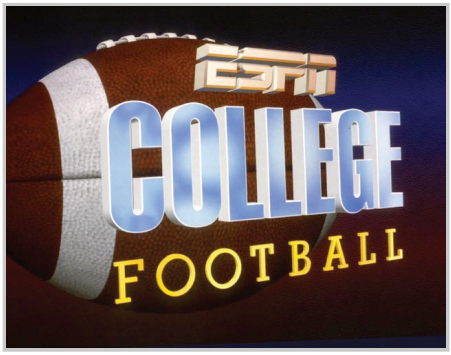
Lombardi Trophy – part of NFL SuperBowl promotion



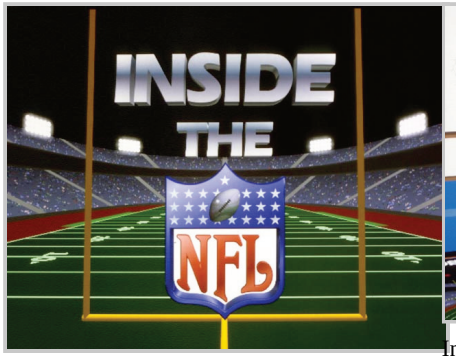
ESPN College Basketball show open



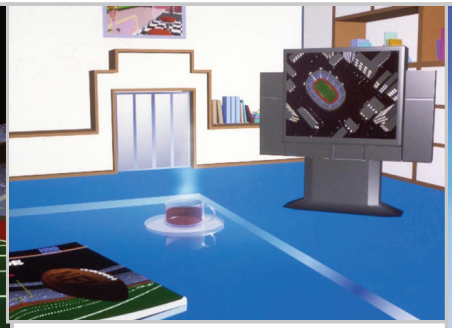
ESPN College Basketball show open



ESPN College Football show open



Inside the NFL show open



Inside the NFL promotional graphics



Wimbledon tournament graphics



Wimbledon tournament highlights promotion



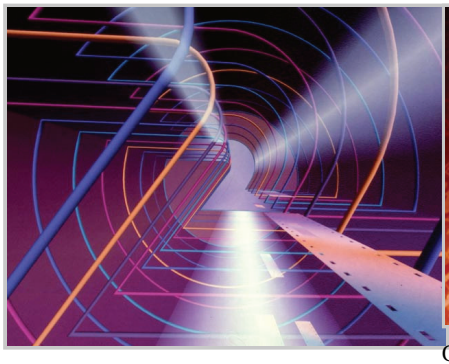
CBS Final Four animation



NBC Breeders Cup promotional graphics



ABC affiliates promotional graphics



ABC affiliates promotional graphics –
Channel 2 in New York



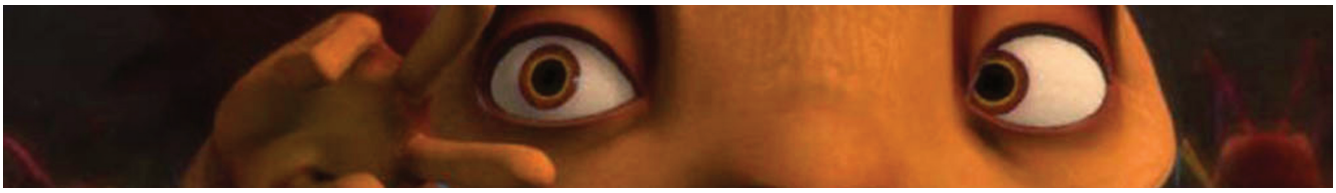
Channel 4 Detroit graphics



The Body Machine graphics

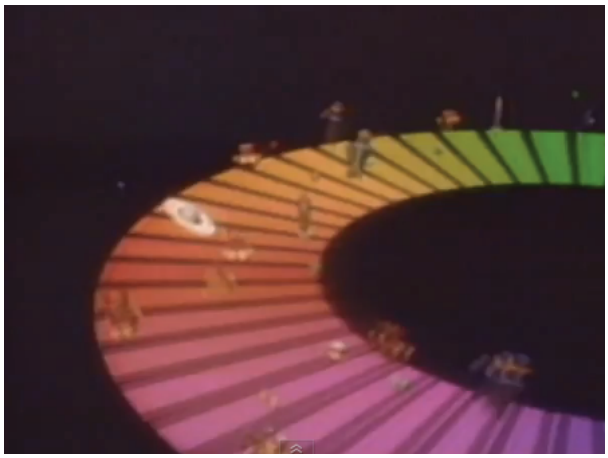


6.7 Pacific Data Images (PDI)



PDI logo

Pacific Data Images (PDI) was started in Los Altos, California in 1980, by **Carl Rosendahl**. He was soon joined by Richard Chuang (1981) and Glenn Entis (1982) and they moved to Sunnyvale.



Frame from early PDI video reel

Rosendahl contracted with Rede Globo in Brazil to develop software for their television promotions for the network, and designed some early show opens and specials. As a result, this helped finance the development of their software environment, which included an animation scripting language, modeling, rendering and motion design programs, all written in the C programming language. They started their production using DEC VAX systems, but were instrumental in introducing what was called the "superminicomputer" to the production world, in the form of the Ridge 32 computer. It was 2-4 times faster than the VAX 11/780 at a fraction of the cost, and its virtual memory allowed PDI to expand beyond the 2MB memory limitation of the VAXen. Much like Cranston/Csuri, PDI focused on direct to video production, as opposed to the film output that was being done at Abel and Digital Productions. While CCP used a modified Electronic Still Store (ESS), PDI modified the interface to a Sony BVH-2000 in order to do single frame recording. They also used an IMI500 for motion design.



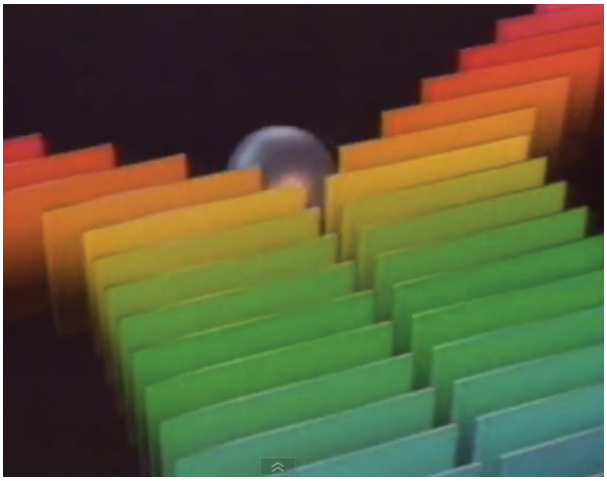
Carl Rosendahl



Glenn Entis



Richard Chuang



Frame from Rede Globo promotion

Some of the early production contracts included Globo, an Emmy award winning open for Entertainment Tonight (produced for famed promotion designer Harry Marks[1]), ABC Sports 84 Olympic promos, NBC News, the Doughboy for Pillsbury, Crest, and Bud Bowl, etc. While the early focus was on TV network productions (they captured over 50% of that market in 1985), PDI introduced the digital film scanning process in 1990, which they used to popularize automated rig removal and image touchup. They also were instrumental in introducing performance animation for theme parks, ads and movies, starting with a project (Waldo)[2] with Jim Henson Productions for a real time performance character.

1. Harry Marks is an award-winning broadcast designer and co-founder with Richard Saul Wurman of the Technology, Education and Design (TED) Conferences,or TED talks. He was the producer for films such as *Mad Dogs and Englishmen*, and was widely known for his work with ABC television. The Monterey Herald reviewed his career in an article in 2013.
2. From the Muppet Wiki website: "Despite his CG nature, Waldo was controlled in real time by a puppeteer, making use of a mitten-like motion-capture device called a waldo (which he was named after). Jim Henson had begun experimenting with creating digital characters in the mid-1980s and Waldo's underlying technology grew out of experiments conducted to create a computer generated version of Kermit the Frog. Waldo's strength as a computer generated puppet was that he could be controlled by a single puppeteer in real-time, in concert with conventional puppets. The computer image of Waldo was mixed with the video feed of the camera focused on physical puppets so that all of the puppeteers in a scene could perform together. Afterward, in post production, he would be re-rendered in full resolution, adding a few dynamic elements on top of the performed motion. Waldo's design was led by Kirk Thatcher with input from a variety of other artists, including Timothy Young (who provided concept sketches) and animated by Pacific Data Images, later known as PDI/DreamWorks. Thatcher was greatly influenced by Chris Wedge's 1987 CG Short, *Balloon Guy*". Waldo C. Graphic was presented in Boston at SIGGRAPH. *Walters, Graham. The Story of Waldo C. Graphic. Course Notes: 3D Character Animation by Computer, ACM SIGGRAPH '89, Boston, July 1989, pp. 65-79*

Commercial popularity of morphing was helped along with a music video, *Black and White*, produced for Michael Jackson in 1990. They broke into the movie production business with contributions to such films as *Batman Forever, The Arrival, Terminator 2, Toys, Angels in the Outfield*, and produced the 1998 fully CGI hit *AntZ*. They also produced the Simpson's Halloween Special Homer in 3D in 1995.



Frame from Entertainment Tonight show open

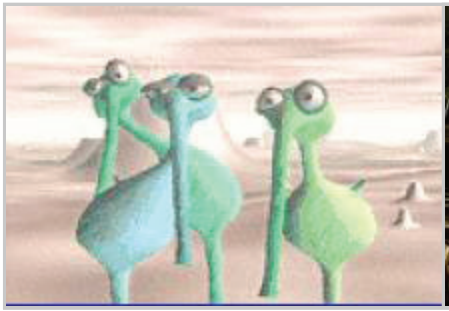


Frame from The Simpsons, Homer in 3D

The strengths of PDI include character animation, lip synch, rendering effects, the aforementioned **rig removal** and cleanup, and **performance animation**. The industry has acknowledged that their employee-focused approach to business helped them succeed where others failed. PDI always had a history of letting their animators pursue individual projects and shorts, and they produced award winners in this category, including: *Opera Industrial (86), Chromosaurus, Cosmic Zoom and Burning Love (88), Locomotion (89), Gas Planet (92), Sleepy Guy and Bric-a-Brac (94*).



Frame from Chromosaurus



Frame from Gas Planet



Frame from Locomotion

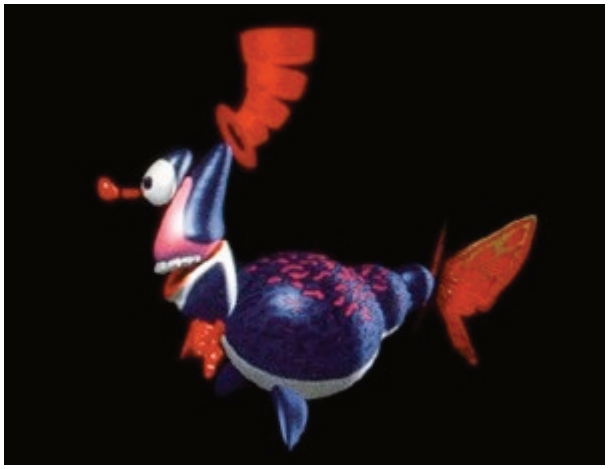
Entis left PDI for the game industry in 1995, joining Dreamworks Interactive (then Electronic Arts) as CEO. He earned a Scientific and Technical Award from the Academy of Motion Picture Arts and Sciences, was a founding board member of Los Angeles' Digital Coast Roundtable, and was chairman of the Academy of Interactive Arts & Sciences. Carl Rosendahl sold his interest in PDI and left in 2000 to become managing director for Mobius Venture Capital and a board member of iVAST, an MPEG4 software company, and several other Bay Area technology firms.



PDI Headquarters

The Academy of Motion Pictures Arts & Sciences (A.M.P.A.S.) recognized PDI's proprietary animation system with an Oscar, a technical achievement award in 1997. PDI R&D team-member, Nick Foster, was awarded a 1998 A.M.P.A.S. technical achievement certificate for his development of software tools built to simulate water and fluid.

In March 1996, PDI signed a co-production deal with DreamWorks SKG to create original computer-generated feature films, including *Antz*. In February 2000, DreamWorks acquired the majority interest in PDI to form PDI/DreamWorks. Under this union, *Shrek*, PDI's second animated feature film, hit theaters in spring 2001, and *Shrek 2* in 2004, and PDI also developed the movie *Madgascar*.



Waldo C. Graphic, produced for Jim Henson

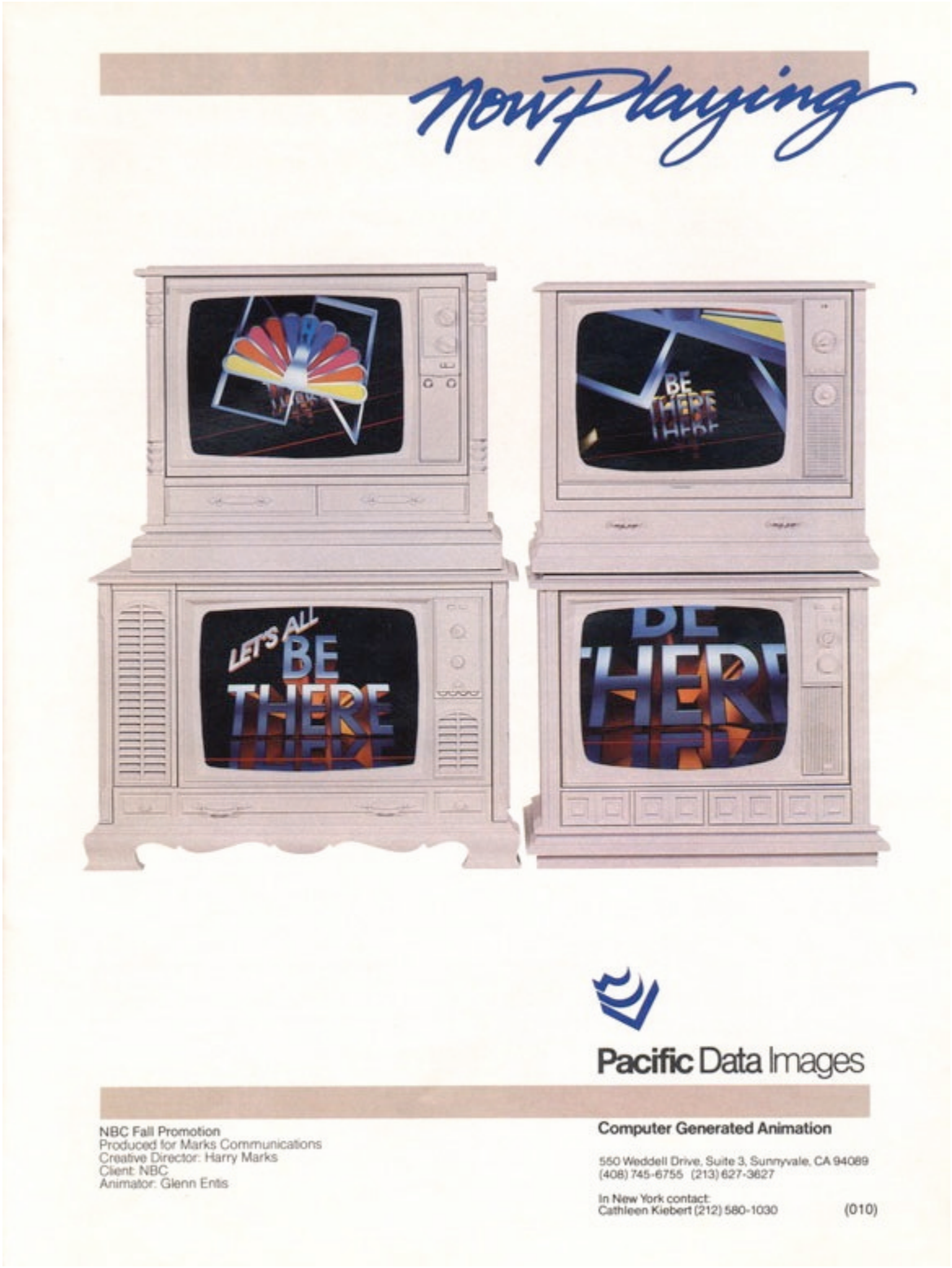


Customizable television network promotional spots were a staple for graphics production companies in the 1980s, including this PDI graphic produced for CBS

Movie 6.31 PDI Morphing



Famous morphing process produced by PDI for the Michael Jackson Black or White video.
https://www.youtube.com/watch?v=0b1_4NI3XIM



PDI Ad from 1984 Computer Pictures Magazine

Movie 6.32 Pacific Data Images demo (1983)
https://www.youtube.com/watch?v=b0cHnFxxLC4

Movie 6.33 Locomotion
http://www.youtube.com/watch?v=468W7XW4Kpg

Movie 6.34 Chromosaurus (1985)
http://www.youtube.com/watch?v=HOUYSLStGak

Movie 6.35 Jim Henson demonstrates the Waldo system and Waldo C. Graphic
https://www.youtube.com/watch?v=dP6TUB7KQc4

Movie 6.36 Richard Chuang presents the 25 year history (1 hour)
http://www.youtube.com/watch?v=cQkEA62KWQQ

In November of 1998, Pixar released their hit movie about ants, called *A Bug's Life*. But a little more than a month earlier, Dreamworks released their ants movie, called *Antz* (produced by PDI). As was often the case in the CGI world in the 1980s and 1990s, PDI and Pixar people were friends and healthy rivals, even co-sponsoring a famous party at the annual SIGGRAPH conference. So it seemed like more than coincidence that these two studios released a movie about ants at the same time. Peter Burrows of BusinessWeek writes about the ensuing controversy in his article *Antz: vs Bugs: The Inside Story of How Dreamworks Beat Pixar to the Screen* in the November 1998 issue.[3]

3. This article is no longer available online. It was summarized in a Wikipedia page for the movie *A Bug's Life*, with other references added. An excerpt from this summary can be viewed at *https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/09/Antz-vs-Bugs-summary.pdf*

6.8 Omnibus Computer Graphics





Omnibus creative team: Keith Ballinger, Kim Davidson, Dan Philips, John Stollar (from 1986 Shareholder Report)

Omnibus was founded in Toronto. They were originally in the business of marketing and communications, and expanded into video production. They founded Image West in Hollywood in 1975. Image West primarily used analog video for production, including the famous *Scanimate* (more about Scanimate can be found in Chapter 12.) In the late 70s, *Image West* split from Omnibus.

In 1974, they hired **John Pennie** as President, and they established Omnibus Video, Inc. in 1981 (using the NYIT Tween software), and Omnibus Computer Graphics in 1982. The produced the first CG commercial in Canada in 1983, and went public later that year.They opened an office in New York in 1984.(which was headed by George Heywood) , and in 1986 purchased Digital Productions for 800,000 shares of stock valued at $12M, and Robert Abel and Associates for $7.3M to establish a presence in Los Angeles in the film world. They also opened a Japanese facility.

Omnibus purchased the Foonly F1 from Triple-I and placed it on the Paramount lot. The investments that allowed for the takeovers of DP and Abel were in part due to predictions by Pennie that investors would see income of upwards of $55M per year. They consolidated the efforts of the three companies and initially laid off 50 people. As a result of the extremely fast expansion and alleged discrepancies in the stock offering, they accumulated a $30M debt, including losses of $5.9M in one quarter alone.[1] As a result, they closed the doors on the combined companies in October of 1987, thus closing the three CGI powerhouses in one fell swoop. Almost 150 people were affected by the closure. This became known as DOA day (Digital-Omnibus-Able).



Canadian Broadcasting Company



Flight of the Navigator

Omnibus productions (pre DP/Able) include *Explorers, Flight of the Navigator, Wonderwork*s, and the promotion for the Vancouver Expo. The PRISMS software (funded by a grant from the Canadian government) developed at Omnibus was sold to former employees Kim Davidson and Greg Hermanovich who started SideFX Software in 1987. They currently market the Houdini software product.

The following article is from an issue of the Canadian publication *Graphics Exchange*:

Technology Stories Your Grandfather Never Told You

JOHN PENNIE WAS A CANADIAN BOY WITH A DREAM. He knew without a shadow of a doubt that there was a big, bright future in computer graphics, and he was determined to be part of the big boom when it happened.

In 1982 he started a company called Omnibus . By 1984, Pennie had Omnibus steam-rolling; slick annual reports and state-of-the-art computer animation studios in Toronto and Los Angeles made it easy for Pennie to dazzle heavyweight investors with high tech glitz and the promise of having a piece of the digital future.

1. From CG101, quoting Dave Sieg: The Omnibus management knew nothing about computer animation, but kept muttering about "Economies of Scale". The reality was: three separate sales forces, three separate production crews, three separate facilities, philosophies, software systems and hardware systems, none of which were likely to ever work together. What is ironic is that the next Star Trek movie was about to go into production, and had tons of CGI work in it. We had good contacts with the right people, and we did some amazing tests (I have videotape!) of the Enterprise that blew the modelmakers away. But they were too scared Omnibus would go under to give us the contract that would have saved us

In Canada, Pennie could point at the whirling logos of CTV and CBC on any television set to demonstrate how his company was on the leading edge of the industry.

But Pennie still wasn't satisfied. His ultimate goal was to own the computer graphics industry – all of it. This was the 80s – the Me decade, the decade of big bucks, and bigger bucks always just around the corner. In 1986, Pennie landed a really big sugar daddy, in the form of the Royal Bank. He had a megaplan, and now he was ready to go into action – south of the border.

The two largest computer graphics companies in the United States at that time were Digital Productions and Robert Abel & Associates Inc. In June, 1986, backed by various investors and $6 million of the bank's money, Omnibus swallowed Digital. In October, it dropped $7.3 million to take over Abel & Associates. Pennie could see his dream starting to unfold. Omnibus now controlled the North American computer graphics industry (and had a pair of $13 million Cray supercomputers to prove it). Unfortunately, the founders and management of these two companies didn't share Pennie's grandiose vision, and they got out fast.

The dream didn't last long. By March, 1987, Omnibus was sinking under the weight of $30 million in debt and in default on its loan agreements; in May it was in bankruptcy, leaving the American computer graphics industry in ruins. Omnibus was omnibust, and the cream of the continent's digital animators were out on the street.

Such is the nature of influence. One individual's actions can alter the course of a whole industry. In the case of John Pennie, his overzealous attempt to dominate an industry wound up shattering it. Yet the demise of Omnibus spawned a host of smaller, more aggressive companies throughout the U.S. and Canada (one of which is Toronto's Side Effects Software) and the computer graphics industry successfully regenerated itself with new technologies and new visions to become what it is today.

Movie 6.37 Omnibus demo



1985 commercial demo reel for Omnibus Computer Graphics
https://www.youtube.com/watch?v=K18ZcE2t1Kw

6.9 Bo Gehring and Associates



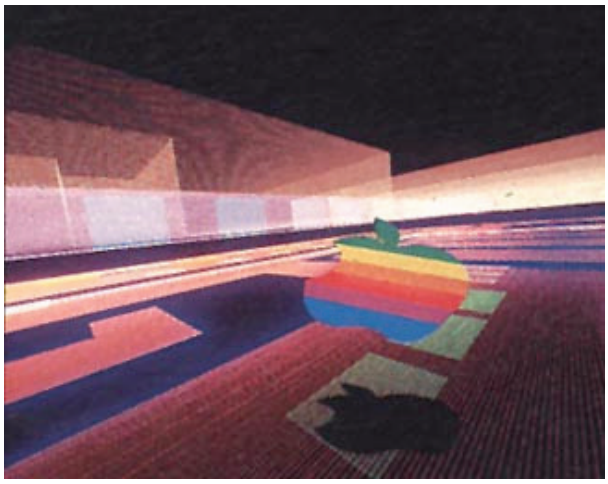


Bo Gehring

Bo Gehring was at Cornell University in Electrical Engineering when he became interested in design. He quit the EE department in 1961 and worked with welding metal sculptures and running a machine shop. When the computer industry expanded, his shop was hired to design and build computer-controlled drilling machines for IBM circuit boards. Gehring was hired by Phil Mittleman of MAGI in 1972 to develop the division of the company focused on computer image making (MAGI Synthavision). Gehring later moved to LA to create test sequences for Steven Spielberg's *Close Encounters of the Third Kind*. and started his own company, Gehring Aviation, in 1977. He later renamed the company as Bo Gehring and Associates, which focused not on the film industry but the advertising industry[1].

1. There were many small, boutique type production companies contributing to the CGI industry in the late 1970s and early 1980s. Gehring is an example of the kind of company that was important to the evolution of the industry.

Gehring produced animation for the films *Demon Seed* (1977, with Julie Christie and Fritz Weaver) and *Nightmares* (1983, with Emilio Estevez and Moon Zappa). He also worked with the famous television promotion producer *Harry Marks*. Although the film industry beckoned those companies in LA, Gehring chose to stick with television. "Ninety million dollars is spent each day on advertising in the United States," Gehring told *Greg Bear* in an interview. "Feature films can't begin to match that level of financing. I'm secure where I am."

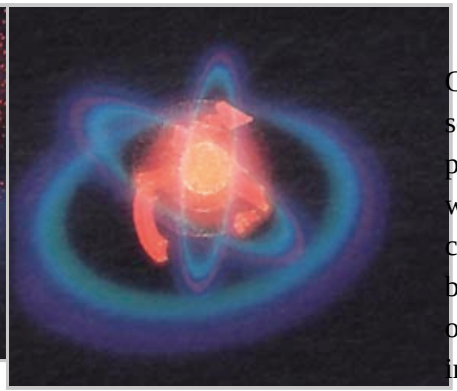


Apple Computer ad produced by Gehring

Two years later, Gehring was producing about half of his work for feature films, and the other half for advertising at Venice-based Gehring and Associates. His "boutique" business had several motion control tracks and several high end vector and raster systems, but he often did the front end design for productions, and contracted with other companies (eg, Triple-I and Cranston/Csuri) for the image computation and compositing in order to keep his capital costs at a minimum. This focus on software investment at the "front-end" resulted in the development of one of the first film scene tracking software algorithms (STAR- Scene Tracking Auto Registration), a sort of electronic **rotoscoping** system (assistance in the coding was provided by Jim Clark, later of SGI fame).



Frame from ABC promotion



Frame from KCOP-TV promotion

Gehring also was interested in digital sound synthesis. "I'm one of those people who has to pull off the road when something really intriguing comes on the car radio. I firmly believe that sound is at least the equal of sight in bandwidth– complexity of information–and synthetic sound is a fascinating area that's barely been explored." (also from the Greg Bear interview) After the closing of his Venice based company, he moved to Canada for a stay at Banff, where he pursued his audio interest, starting a company called Focal Point to develop software for the Mac.

According to Gehring: "The Focal Point 3D Audio system takes any sound and processes it to generate signals for each ear. It's a cursor for the sound," he explained. "It's the same sound as before, but built into it is new information to make the brain think it's coming from a new direction". He also has been involved with a design company, Third Rail Ops, and resides in Beacon, New York. According to their website, Third Rail Ops "provides design and production support to artists and architects. At the heart of the practice is a projection theater where works are visualized full size in three dimensions. The latest computer technology, in-house CNC machining, large format printing, and a seasoned network of services such as rapid prototyping and large-scale fabrication complete the picture."

Gehring recently won the 2013 Outwin Boochever Portrait Competition. He conceived and executed a short video of Esperanza Spalding that was included in the national portrait gallery of the Smithsonian [2]



Gehring ad from 1983 Computer Pictures trade magazine

Movie 6.38 Gehring demo reel

2. "A vein on the left side of Esperanza's neck pulses; the fabric of her dress accordions faintly out and in with each breath; her finger twitches and grains of mascara ride eyelids that halfway conceal two smiling eyes. Welcome to the intimacy of slow and the close-up video portraiture of Bo Gehring on view in the Smithsonian's National Portrait Gallery exhibition *Eye Pop: The Celebrity Gaze*." http://www.e-torch.org/2016/03/up-close-and-extremely-personal-the-video-portraiture-of-bo-gehring/ He has a video that shows the portrait creation process at http://www.bogehring.com/VIDEO/portraits/how_it_works_video.html



1983 commercial demo reel from Bo Gehring & Associates https://www.youtube.com/watch?v=Es8VdR-E8Wg

Movie 6.39 Marks and Marks Demo (Harry Marks 1981)

http://www.youtube.com/watch?v=6c3nWhR41D0

Chapter 7: Organizations, conferences, & graphics standards

Organizations, conferences, & graphics standards

Several professional organizations grew with the emerging computer graphics industry. These organizations started some conferences, including the influential ACM-SIGGRAPH conference, and attempted to define important standards for the discipline.



7.1 CG Organizations and Conferences





IEEE Logo

The IEEE Computer Society is the world's leading organization of computer professionals. Founded in 1946, it is the largest of the 37 societies of the Institute of Electrical and Electronics Engineers (IEEE) with nearly 100,000 members.

In 1947, members of the computing community founded a professional organization called the Association for Computing Machinery (ACM), to provide professional and educational opportunities for its members. It has grown to approximately 75,000 members from every area of the computing related field.



ACM Logo

The American Federation of Information Processing Societies (AFIPS) was established on May 10, 1961, to advance and disseminate knowledge in the field of information science, and to represent member societies on an international level. The federation was an outgrowth of the National Joint Computer Committee, which was established in 1951 to sponsor the Joint Computer Conferences. The founding societies of AFIPS were the Association for Computing Machinery (ACM), the American Institute of Electrical Engineers, and the Institute of Radio Engineers (the latter two eventually merged into the IEEE, or Institute of Electrical and Electronic Engineers). One of the main contributions of AFIPS was its sponsorship of the Joint Computer Conference, renamed the National Computer Conference in October 1973. These semi-annual conferences featured technical sessions and exhibits relating to the field of information processing. They were discontinued after 1987 because of the financial condition of the organization

One of the unique components of the ACM organization is the Special Interest Group, or SIG (in the early days they were called Special Interest Committees, or SICs). The individual computing specialty areas are represented in one of these 35 SIGs. Like the umbrella ACM organization, each SIG is governed by a board made up of volunteer members.

In 1967, one of the ACM Board members was Sam Matsa, who started his career as part of the IBM/GM

relationship that would result in DAC-1 and the IBM 2250 display. Matsa and Andy Van Dam of Brown University organized a professional development seminar in graphics as part of a larger series of seminars. Matsa convinced ACM to sponsor these seminars, which traveled around the country, attracting 40 or 50 people to each. In the graphics seminar, Van Dam taught the hardware side and Matsa taught the software component.



SIGGRAPH 84 Logo

As a result of the interest in the graphics discipline, evidenced by the attendance at these seminars, Matsa and Van Dam convinced ACM that they should recognize a Special Interest Committee in Graphics, and SICGRAPH was born. Matsa was the founding Chairman and Van Dam as Secretary organized the SIC newsletters.

In 1969, the members wanted recognition of the area in the way other computing disciplines were recognized, with elected rather than appointed officers, so a lobbying effort resulted in enough signatures to convince ACM to give the SIC a Special Interest Group designation, and ACM-SIGGRAPH was established. Its first elected chair was Ed Devine. Jon Meads named it SIGGRAPH: the Special Interest Group on Computer Graphics and Interactive Techniques in the bylaws, in order to recognize the graphics and the human interaction parts of the equation.

The organization participated in the broader ACM conferences, and published a quarterly newsletter. Interest ran the gamut from simulation and modeling, to text editing and composition, to computer generated art, cartography and mapping, computer aided design and, computer graphics software and hardware.



SIGGRAPH Logo

In 1973, Meads and Bob Schiffman organized the first annual SIGGRAPH conference, which has become one of the compelling aspects of the organization. It was held in Boulder, Colorado in the summer of 1974 as the 1st Annual Conference on Computer Graphics and Interactive Techniques. Attendance was approximately 600 people. There were no formal proceedings published, rather the papers were included in an obscure journal from Pergammon Press. The next two conferences, at Bowling Green, Ohio and Philadelphia, were only moderately successful. In 1977 the conference was held in a Hyatt in San Jose, and it was a resounding success, leading to decades of successful and important SIGGRAPH conferences. The Proceedings of the Conference remains an accepted scholarly journal for the publication of technical contributions.

Tom DeFanti, who graduated from Ohio State and later served as SIGGRAPH Chair, organized film and video presentations in the early conferences, and in 1979 started publishing them as the SIGGRAPH Video Review. These sessions are now called the Electronic Theatre, part of the Computer Animation Festival, a juried conference event. In 1995, Frank Foster arranged to have this evening of visuals in a formal theatre setting, away from the conference venue, at the famous Shrine Auditorium in LA.

Over the years, Panels and Courses were added, an Art Show became a mainstay, and venues for emerging technologies were provided. Several related conferences have occasionally co-located with SIGGRAPH, and an Education track became part of the overall conference offerings.

The above section is based in part on an article in the SIGGRAPH newsletter by Carl Machover. http://www.siggraph.org/

NCGA Logo

The National Computer Graphics Association (NCGA) was founded in 1979 by Joel Orr and Peter Preuss. It evolved from the standardization efforts of SIGGRAPH, and some frustration that the industry was not necessarily being served well by a single entity in the form of SIGGRAPH. It held its first conference in Virginia in 1980, with an expanded equipment exhibition, workshops and tutorials for attendees, and an award program for images and videos (SIGGRAPH chose not to pick any "best of…" until 2003.) For many years, it was important for graphics professionals to attend both conferences, but during the downturn in the 90s, NCGA fell on financial hard times, and is now defunct. Several subgroups of NCGA, such as the CAD Society have survived. It is an occasional informal gathering of professionals–vendors, consultants, and users–who are interested in CAD.



First UAIDE Conference

In 1980, the European Computer Graphics Organization, Eurographics was formed. They held their first conference in Geneva that year. There were also organizations in Australia (Ausgraph), Canada, the Netherlands (ISEA – The Inter-Society for the Electronic Arts), Japan (Nicograph's first conference was held in 1982) and elsewhere. The CGS (Computer Graphics Society) was formally founded in Geneva in 1992. Also, beginning in 1962 the Users of Automatic Information Display Equipment (UAIDE) annual conference was the home for leading edge computer graphics papers until SIGGRAPH came along. During the mid-1980s, Pratt Institute in New York sponsored an annual conference (ComGraf), and there were conferences in Paris (Parigraph), London (ComputerFX), MonteCarlo (Festival International de Television de Monte Carlo), Canada (Graphics Interface), and many other locations in the U.S. and abroad. Besides SIGGRAPH and NCGA, a big conference for CAD professionals was the Design Automation Conference. *(See Machover's UAIDE discussion in the May 2000 SIGGRAPH newsletter).*

Eurographics was formally founded in spring 1980. Under the chairmanship of José Encarnação, it was given its first operational structure, composed of an Executive Committee, an Executive Board, a Workshops and Books Board, a Professional Board and a Conference Board.

Two years later, the British Chapter was founded. The Computer Graphics Forum started and first contracts were made with ACM-SIGGRAPH (USA), Austrian Computer Graphics Association (A), British Computer Society (UK), Gesellschaft fuer Informatik (D), the J. von Neumann Society (H) and the NCGA (USA). In 1984, now under the chairmanship of Paul ten Hagen, the German Chapter followed. Affiliation agreements between GI (D) and EG, and between SIGRAD (S) and EG were made in 1985.

In 1986 Carlo Vandoni took the lead, and in June, Eurographics was registered at the "Registre du Commerce" in Geneva. The Spanish Chapter was founded 1987, the Portuguese Chapter followed only a year later. Moreover, affiliation agreements with the Austrian Computer Graphics Association (ACGA), the German Computer Society

(GI), the Norwegian Computer Graphics Scociety (NORSIGD) and the Swedish Graphics Interest Group (SIGRAD) were made along with liaison agreements with societies in China and Japan.

The years 1987-1988 represented a period of stabilization for the Eurographics Association with respect to the number of individual and institutional members thanks to various promotional activities. Also, the services offered to members improved considerably: student and spouse membership were introduced, the CGF appeared at rather regular intervals and discounts to members for IEEE CG&A and for the Springer series were offered.



Eurographics Logo

More affiliation agreements were made with the French Computer Society (AFCET), the Italian Computer Society (AICA), the Finnish CAD/CAM Association, the Dutch Computer Society (NGI) and with the Swiss Computer Graphics Association (SCGA) and the Nicograph Association in 1989 and 1990 under the chairmanship of Roger Hubbold. Under his lead, the EG conference proceedings were made a special issue of CGH. Furthermore, the official EG logo was created at that time, programmed by hand in PostScript.

At this time, the working groups for Pictures and Multimedia, Computer graphics and AI, Computer graphics Hardware, Scientific Visualization, Relationships Between Image Synthesis and Image Analysis were established.

In 1991, Jürgen Schönhut was elected chairman of the EG Association. The Editor of Computer Graphics Forum changed to NCC Blackwell Publishers and H.P.Seidel was announced its new chief editor. In 1992, David B. Arnold took over as Chair. A new agreement with Springer Verlag to publish the Eurographics Workshops in the new “Focus on Computer Graphics” series was made in 1993. EG started its web presence in 1995 by establishing its website under the lead of Ivan Herman.

In May 1996, on a workshop on the future of Eurographics, the main focus of EG was set as “an association of professionals to help professionals in their careers in computer graphics and interactive digital media”. Under the presidency of W.T.Hewitt, a liaison agreement with the Chinese Computer Graphics association was also signed that year. In the following year, the Eurographics publications catalogue got inaugurated on the website www.eg.org, replacing the printed catalogue.

In 1999, under the lead of Dieter Fellner, the Online Board was instated and the cooperation agreement between Eurographics and SIGGRAPH was renewed. In 2000, due to this cooperation, EG for the first time was operating a stand outside the exhibition area and next to the SIGGRAPH, being a vital sign of EG and showing its standing in the graphics world. In the same year, a cooperation with IEEE TCVG was signed and the digitization of back issues of Computer Graphics Forum started.

The Italian Chapter was founded in 2001 under the presidency of P.Brunet. In 2003 the French Chapter started.

(From History page of the EG website *https://www.eg.org/index.php/about-eg/history*)

7.2 Graphics Standards



In 1916 the American Institute of Electrical Engineers (now IEEE) invited the American Society of Mechanical Engineers (ASME), American Society of Civil Engineers (ASCE), American Institute of Mining and Metallurgical Engineers (AIMME) and the American Society for Testing Materials (ASTM) to join in establishing a national body to coordinate standards development and to serve as a clearinghouse for the work of standards developing agencies.

Two years later, the American National Standards Institute, or ANSI, originally founded as the American Engineering Standards Committee (AESC) was formed to serve as the national coordinator in the standards development process as well as an impartial organization to approve national consensus standards and halt user confusion on acceptability. The five organizations invited the U.S. Departments of War, Navy and Commerce to join them as founders.?(See *http://www.ansi.org*)

The International Organization for Standardization (ISO) was established in 1947 to define “specifications and criteria to be applied consistently in the classification of materials, in the manufacture and supply of products, in testing and analysis, in terminology and in the provision of services.” In the field of CG, this can mean applications portability, graphics package portability, host machine independence, device independence, programming language independence, interoperability, and perhaps even programmer and operator portability.

The standardization process in CG started in the mid-60s. A number of software packages helped define “de-facto” standards for the portability of graphics programs. For example, Plot-10 from Tektronix, Cambridge University’s GINO-F and Culham Lab’s Ghost all provided for certain standardization, but there were problems with each of them. Also, there were european efforts for standardization that were progressing, most notably the German Standards Institute, or DIN, and the Norwegian group which proposed a package called GPGS as a standard. GPGS later became known as IDIGS.

The International Federation of Information Processing, or IFIP, is a non-governmental, non-profit umbrella organization established in 1960 for national societies working in the field of information processing. It established Technical Committees, or TCs (Foundations, Software Theory and Practice, Education, Applications,

etc), each of which established Working Groups, or WGs, responsible for different activities within the context of the TC.IFIP WG 5.2, Computer Aided Design , belongs to IFIP TC 5, Computer Applications in Technology. It was established in 1972, and revised in 1986.

In 1972, ACM established an informal Graphics Standards Planning Committee, or GSPC. They met periodically, and discussed ideas that could possibly result in some kind of standardization. They organized and held a Workshop on Machine Independent Graphics at the National Bureau of Standards in 1974, and formalized themselves as the GSPC, but their activities soon (in the words of Robin Williams) languished for a few years.

In May of 1976, a Workshop on Graphics Standards Methodology was organized by Richard Guedj under the auspices of IFIP WG 5.2 in Seillac, France. Called Seillac I, the workshop was attended by representatives from all over the world who all agreed that it was extremely important to develop a sound methodology, and perhaps a new language conforming to that methodology. The Seillac workshop decided 1) to begin the standardization efforts with the application program interface, or API, 2) to separate the modeling of a scene from the viewing of a scene, and 3) to assure language independence.

*SIGGRAPH 77 Proceedings cover*During the SIGGRAPH 76 conference, GSPC was reactivated. Bob Dunn and Bert Herzog became the leaders of a group of 25 expert volunteers, divided into groups to deal with short-term issues and longer-term core issues that were identified both from their previous work as well as the Seillac workshop. In particular, they decided that a “State of the Art” group would survey existing software packages and approaches; a “Methodology group would look at a conceptual framework and guidelines; a “Core” group to define the semantics of a standard graphics package; and an “Interface” group that would consider interoperability with other software technologies. The Core recommendations were published in a supplement to the Proceedings of the SIGGRAPH 77 Conference.



SIGGRAPH 77 Proceedings cover

ISO also established a working group, ISO WG2, the Graphics Working Group, to study the issues. They met in Bologna in 1978 and considered reports from DIN, the GSPC Core group, and IDIGS. The DIN report was called GKS, or Graphical Kernal System, which unlike Core, only dealt with 2D. They met again in Amsterdam in early 1979, and recommended that GKS and Core come closer together. DIN and GSPC met in Boulder, Colorado to discuss these recommendations.

In June, 1979 the Core work was passed to ANSI, which organized a working group called X3H3 to develop a standard based on Core. X3H3 ultimately recommended a standard called PHIGS. In the meantime, an ISO workshop was held in Budapest in October, 1979 to consider GKS version 5.0, as well as Core and a version of IDIGS. It decided to focus on GKS only. Following discussions at the Eurographics Geneva conference, the proposal for GKS as a two-dimensional standard for Computer Graphics was submitted to ISO. Some think that if the SIGGRAPH Core proposals had been submitted to ISO in the previous year then it is probable that ISO would have considered a two-dimensional standard unnecessary, but the GSPC had neglected to do this. The submission of the GKS proposal to ISO was followed by lengthy discussions with all interested parties and some of the ideas of the Core, especially those relating to forms of text output, were incorporated into GKS before it was published in 1982 as Draft International Standard 7942.

Discussions continued on minor details of 7942, and it has been said that the GSPC were not happy with the emergence of GKS. SIGGRAPH organized a vote of its members to decide whether it or ISO should be the appropriate authority to decide on standards for Graphics in America and the vote fell solidly in favor of ISO. In February 1984, SIGGRAPH published a special issue describing GKS which was sent to all its members, and it became the first published standard for graphics in August, 1985.

GKS defines a basic two-dimensional graphics system with uniform input and output primitives and a uniform interface to and from a GKS metafile for storing and transferring graphics information. It supports a wide range of graphics output devices including such devices as printers, plotters, vector graphics devices, storage tubes, refresh displays, raster displays, and microfilm recorders. As the technical work on GKS came to a close, attention was turned to issues of 3D. Some wanted to extend GKS, while others, most notably the U.S. introduced a new system, called PHIGS. It was agreed at a joint meeting in Canada in 1983 to launch both projects.

PHIGS stands for Programmer's Hierarchical Interactive Graphics System. The PHIGS standard defined a set of functions and data structures to be used by a programmer to manipulate and display 3-D graphical objects. The standard was approved by ANSI as ANSI X3.144-1988, by ISO as ISO 9592-1:1989, and by the Federal government as Federal Information Processing Standard (FIPS) 153.

GKS-3D is a pure super-set of GKS designed to handle 3D graphics in a compatible way. That is to say, a 2D application written to the GKS standard is guaranteed to run in a GKS-3D environment without change. However, apart from the usual GKS functions, GKS-3D provides additional ones to handle 3D primitives, 3D input, and 3D viewing. It was standardized as ISO 8806-1 in 1988.

Discussions on the limitations of PHIGS in the area of rendering (output primitives) resulted in the recommendation and adoption of PHIGS+ in 1989.

Work on a Metafile standard for the storage and transfer of picture description information was approved in 1983, and ISO approved the Computer Graphics Metafile (CGM) standard in 1987 as ISO 8632. This standard defines the format of a file that describes one or more two-dimensional images. A CGM metafile is not a picture – it only contains a description of the picture. In order to see the picture, the information in the file must be translated by another program for a specific output device. Pictures are described as a collection of elements of different kinds, representing things like primitives, attributes, and control information.

CAD (Computer-Aided Design) systems had been developing their systems well before the standards activities took place. They were concerned with a metafile for transferring these files between CAD systems. Products may be designed as either a two-dimensional, three-view drawing layout, or as a full three-dimensional model with associated drawing views and dimensions using a CAD system. The Initial Graphics Exchange Specifications, or IGES format serves as a neutral data format to transfer the design to a dissimilar system. Translators, developed to the IGES Standard, are used to export a design into an IGES file for exchange and for importing the IGES file into the destination system.

"In 1979 events took place that catalyzed the CAD vendor community to create the first national standard for CAD data exchange. Mechanical CAD systems were less than ten years old, and there were only a handful of products with any significant market penetration. Even at this early stage, users were overwhelmed by the inability to share data among these tools and with their own internally-developed databases. Frustration was evident at a fateful two-day Society of Manufacturing Engineers (SME) meeting in the Fall of 1979. On the first day, an attendee

from General Electric (GE) challenged a panel of CAD vendors, that included Computervision, Applicon, and Gerber, to work together to enable a common neutral exchange mechanism.

The panel reported on the second day, and the wheels were set in motion to create an 'IGES.' Once the panel admitted that a common translation mechanism was possible, it was impossible to stop the momentum of the customer's enthusiasm and expectations. Applicon and ComputerVision agreed to open their internal databases, GE offered its neutral database, and Boeing offered the structure of its Computer Integrated Information Network (CIIN) database. Both GE and Boeing contributed their existing translators. A core team was formed that included representatives from NBS, Boeing, and GE. Team members had worked closely with each of the vendors on internal integration projects. This prior experience built the expertise and trust needed to craft a solution in a very short time, and neither vendor felt it gave an unfair advantage to the other.



IGES Logo

Soon after, an open meeting was held at the National Academy of Sciences on October 10, 1979. Approximately 200 people attended to herald the birth of IGES." ?*Quoted from B. Goldstein, S. Kemmerer, C. Parks, ", A Brief History of Early Product Data Exchange Standa*

rds" NISTIR 6221, September 1998.

See *http://www.nist.gov/iges/*

The mid-1980s saw the use of CAD playing a more significant role in aircraft design. Boeing decided to design its 777 aircraft totally on the computer, using CATIA. In Europe, a consortium of manufacturers (Aerospatiale(France), British Aerospace, CASA (Spain) and MBB (West Germany)) began the design of the Airbus 320 totally using CAD. The differing systems used by these companies demanded a standard for data interchange, and the SET (Standard D'Exchange et De Transfert) standard was developed. It was seen by many to be the main challenge to the IGES standard evolving in the U.S. SET began development in 1983 at Aerospatiale as a response to the halting implementation of the IGES standard, and because it was developed in one company, its proponents argued that it was faster and more dependable. Others, including U.S. standards officials, saw the emergence of two competitive standards as an impediment to the acceptance of a standard, because of problems of interpretation and agreement among standards makers.

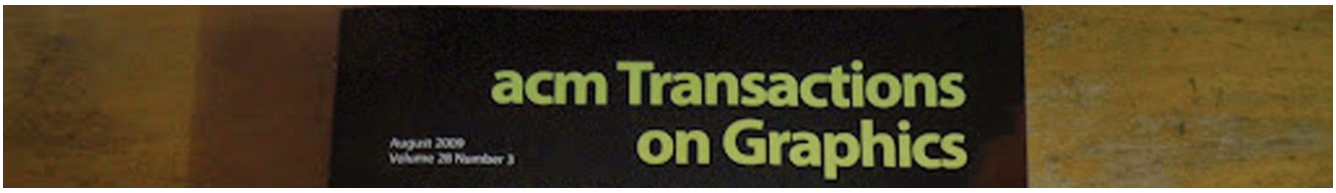
Other standards which have been adopted (some are not official standards, but rather can be considered industry standards) include OpenGL (1992) from SGI, Java-2D and Java-3D from Sun, DirectX (1995) from Microsoft, X-windows (developed at MIT in the late 1980s), PEX (PHIGS extension to X), PostScript, VRML, NTSC (PAL and SECAM), D1 (D2, D3, D5) and many more.

Although it is beyond the scope of this Section to accurately define file formats for graphics, it is worth noting that several have become de facto standards, and several more have come out of actual standards working groups and have either been designated as standards, or are being considered. For example, JPEG is an adopted standard (ISO WG 10, 1991) for encoding and compressing continuous tone raster still images. It was proposed by the Joint Photographics Expert Group, hence its name. Likewise, MPEG (ISO WG11, 1991) is a standard for encoding video and audio sequences, from the Moving Picture Experts Group. Below is a list of some other more popular formats: [1]

1. The National Archives has a detailed description at https://www.nationalarchives.gov.uk/documents/graphic-file-formats.pdf

Format	Developer	Purpose
BMP (BitMaP)	Microsoft	raster; color independence
CCITT	Fax CCITT	document transmission
DXF (Drawing eXchange File)	Autodesk, Inc.	interchange AutoCAD files
EPS (Encapsulated PostScript)	Adobe	describes a single picture that can be included in a PostScript file
GIF (Graphics Interchange Format)	Compuserve	uses LZW compression for transmission over telephone lines; has become a Web standard
JFIF	C-Cube Microsystems	Portable JPEG
PICT (PICTure data)	Apple	optimized for Apple QuickDraw
QuickTime	Apple	storage and retrieval of compressed time-based data
RLE (Run Length Encoding)	University of Utah	device independent raster
TIFF (Tag Image File Format)	Aldus	raster scanned data format

7.3 Early Graphics Publications



Over the years since the graphics discipline began there have been a number of graphics journals and publications, most of which are still being published [1]. They include:

U.S. Journals

- ACM Transactions on Graphics (TOG)
- Communications of the ACM (CACM)
- Computer Graphics (Proceedings of the SIGGRAPH Conference)
- Journal of the ACM (JACM)
- ACM Computing Surveys (defunct)
- IEEE Computer Graphics and Applications (CG&A)
- IEEE Transactions on Visualization and Computer Graphics
- IEEE Spectrum
- Graphical Models and Image Processing
- Computer Graphics and Image Processing
- Computer Graphics, Vision, and Image Processing (formerly CGIP)
- International Journal of Computational Geometry and Applications
- journal of graphics tools
- Computer Graphics World (CGW)
- Graphical Models (formerly Graphical Models and Image Processing)

1. Professor Bill Hill from Jacksonville University, has a recommended list of books and magazines (annotated) on his course website at *http://users.ju.edu/whill/bca/resources.html* that includes some of the above resources and expands it with references to books on computer animation.

- High Performance Computer Graphics, Multimedia and Visualization
- IEEE Transactions on Visualization and Computer Graphics (TVCG)
- Proceedings of the National Computer Conference (defunct)
- Proceedings of the Fall Joint Computer Conference (defunct)
- Proceedings of the Spring Joint Computer Conference (defunct)
- AFIPS (American Federation of Information Processing Societies)
- IBM Systems Journal
- UAIDE (Users of Automatic Inform. Display Equipment) (defunct)

European Journals

- The Visual Computer
- Computer-Aided Design
- Computer Aided Geometric Design
- International Journal of Shape Modeling
- Computers & Graphics
- Computer Graphics Forum, editors
- The Journal of Visualization and Computer Animation
- Computational Geometry
- Machine Graphics and Vision
- IFIPS (International Federation of Information Processing Societies)

Also, popular publications like Scientific American, Byte Magazine, Computer Pictures, Datamation and others have published graphics articles. Esoteric journals in related areas (Journal of Approximation, Applied Mathematics, SAE, …) and proceedings of small conferences were publishing venues for graphics researchers. Several publishers produced newsletters for the industry, including the S. Klein Newsletter, the Roncerelli Report and Pixel News, Joel Orr's Computer Graphics Newsletter (which evolved into Computer Graphics World Magazine), the SIGGRAPH newsletter, and others.

Computer Graphics related books

- R. Bartels, J. Beatty, & B. Barsky, An Introduction to Splines for Use in Computer Graphics and Geometric Modeling, Morgan Kaufmann Pub., 1987.
- M. de Berg, M. van Kreveld, M. Overmars, & O. Schwarzkopf, Computational Geometry – Algorithms and Applications, Springer Verlag, 1997.
- Wolfgang Boehm & Hartmut Prautzsch, Geometric Concepts for Geometric Design, A. K. Peters Pub., 1993.
- J.-D. Boissonnat & M. Yvinec, Algorithmic Geometry, Cambridge University Press, 1998.

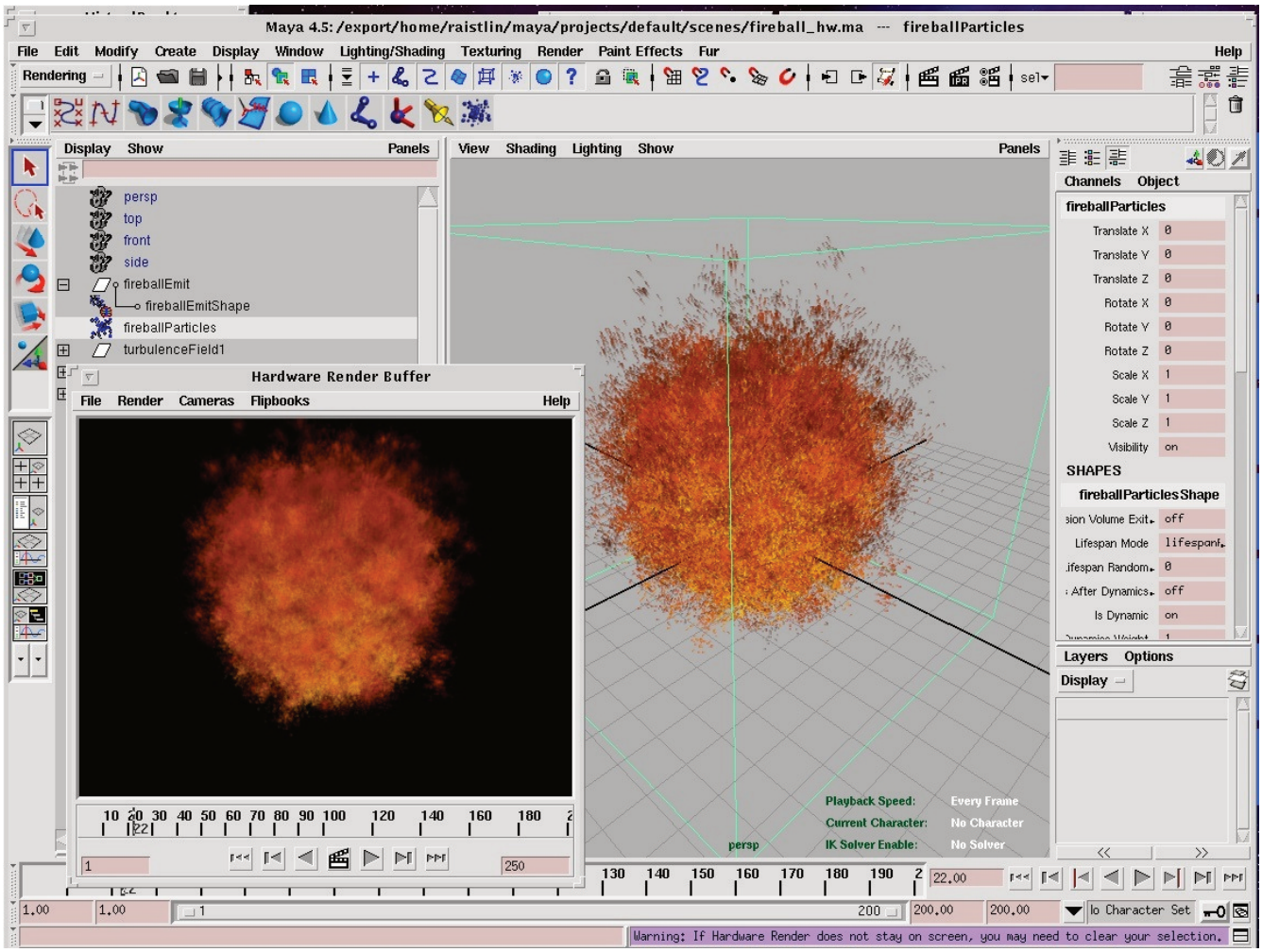
- Michael Cohen & John Wallace, Radiosity and Realistic Image Synthesis, Academic Press, 1993.
- Gerald Farin, Curves and Surfaces for Computer Aided Geometric Design, 4th edition, Academic Press, 1996.
- Gerald Farin, NURB Curves and Surfaces, A. K. Peters Pub., 1995.
- E. Fiume, Mathematical Foundations for Computer Graphics, Academic Press, 1989.
- J. Foley, A. van Dam, S. Feiner, & J. Hughes, Computer Graphics: Principles and Practice, 2nd edition, Addison-Wesley, 1996.
- Andrew Glassner (Ed.), Graphics Gems, Academic Press, 1990.
- S. Harrington, Computer Graphics, A Programming Approach, McGraw-Hill, 1987.
- Andreas Hartwig, Algebraic 3-D Modeling, A. K. Peters Pub., 1996.
- D. Hearn & M. Baker, Computer Graphics, Prentice-Hall, 1986.
- F. Hill, Computer Graphics Using Open GL, 2nd edition, Prentice-Hall, 2000.
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Chapter 8: Commercial Animation Software

Commercial Animation Software

CG researchers and programmers saw the value in taking the software that was being developed in the lab and making it more widely usable, either by selling or licensing it to animation companies.



Scene from Maya Software

8.1 Introduction



The following text was excerpted from an article by David Sturman, from the ACM SIGGRAPH Retrospective series published in the SIGGRAPH newsletter, Vol.32 No.1 February 1998. The entire article can be read at https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/09/sturman-animation.pdf

Perhaps one of the earliest pioneers of computer animation was Lee Harrison III. In the early 1960s, he experimented with animating figures using analog circuits and a cathode ray tube. Ahead of his time, he rigged up a body suit with potentiometers and created the first working motion capture rig, animating 3D figures in real-time on his CRT screen. He made several short films with this system, called ANIMAC. This evolved into SCANIMATE which he commercialized to great success in 1969. SCANIMATE allowed interactive control (scaling, rotation, translation), recording and playback of video overlay elements to generate 2D animations and flying logos for television. Most of the 2D flying logos and graphics elements for television advertising in the 1970s were produced using SCANIMATE systems. In 1972 Harrison won an Emmy award for his technical achievements [25]. As computer graphics systems became more powerful in the 1980s, Harrison's analog systems began to be superseded by digital CG rendered keyframe animation, and now are no longer used in production.

The next widespread system was the GRAphics Symbiosis System (GRASS) developed by Tom DeFanti [at Ohio State University] for his 1974 Ph.D. thesis. GRASS was a language for specifying 2D object animation and although not interactive, it was the first freely available system that could be mastered by the non-technical user. With GRASS, people could script scaling, translation, rotation and color changes of 2D objects over time. It quickly became a great hit with the artistic community who were experimenting with the new medium of CG. In 1978 it was updated to work in 3D with solid areas and volumes and ran on a Bally home computer. This version was called ZGRASS, and also was important in bringing computer graphics and animation to the artistic community on affordable computing platforms [6].

Also in 1974, Nestor Burtnyk and Marcelli Wein at the National Film Board of Canada developed an experimental computer animation system that allowed artists to animate 2D line drawings entered from a data tablet. Animation was performed by point-by-point interpolation of corresponding lines in a series of key frames. The system was

used for 1974 classic short film Hunger whose graceful melding of lines from one figure to the next won it an Academy Award nomination.

The New York Institute of Technology Computer Graphics Lab (NYIT), then under the direction of Ed Catmull, extended this idea, producing a commercial animation system called TWEEN. As with the National Film Board system, TWEEN was a 2D system that allowed the animator to draw key frames, and the computer interpolated corresponding line segments between the keys. TWEEN automated the process of producing in-between frames (sometimes called **tweening**), but still required the talents of a trained artist/animator for the keyframes. Although this method sped up the hand-animation process, animations produced this way had an overly distinctive fluid look and the method was not widely adopted for commercial animation.

The first complete 3D animation systems were typically in-house tools developed for use in particular academic environments or production companies. They could be categorized into two types of systems, scripted or programmed systems, and interactive keyframe systems. The first type were exemplified by ANIMA-II (Ohio State) [11], ASAS [23], and MIRA [16]. All three used a programming language to describe a time sequence of events and functions. When evaluated over time and a "snapshot" rendered at each animation frame, they produced the desired animation. ASAS is noteworthy since many of the CG sequences in the 1982 film TRON were animated with it. These systems were powerful in that almost anything could be done if it could be programmed, but limited in that programming skills were required to master them.

The keyframe systems were more amenable to animation artists. Based on the keyframe approach of traditional animation, these systems allowed the user to interactively position objects and figures in the scene, save these positions as keyframes and let the computer calculate the in-between frames to produce the final animation. GRAMPS [19] and BBOP [28] were examples of this type of system. Both relied on the real-time interactivity of the, then state-of-the-art, Evans & Sutherland Multi-Picture System, an excellent vector-graphics display system that worked from a display list allowing instantaneous updates of the on-screen graphics.

GRAMPS was developed for visualization of chemical structures although O'Donnell does give examples of how it could be used to animate a human figure. Ostensibly an interpreted script system, GRAMPS allowed script variables to be connected to dials for interactive manipulations.

An interesting aside: 2D and 3D animation.

BBOP was developed at the New York Institute of Technology's Computer Graphics Lab (NYIT) by Garland Stern expressly for character animation and was used extensively by NYIT in six years of commercial production. In BBOP, animators could interactively control joint transformations in a 3D hierarchy, saving poses in keyframes which the computer could interpolate to produce smooth animation. The system was very responsive and easy to use, and conventionally trained animators produced some remarkably good animation with it. Examples include a CG football player for Monday Night Football promotions, Rebecca Allen's CG dancer for Twyla Tharp's dance The Catherine Wheel, Susan Van Bearle's short film Dancers and numerous SIGGRAPH film show shorts featuring the digital characters User Friendly, Dot Matrix and User Abuser. These last three were some of the first CG characters to have expressive personalities that engaged the audience and brought CG to life. Much of this was due to an interactive keyframe system that gave the animator the control and freedom to manipulate the figures visually, in keeping with his training and experience.

Most modern commercial keyframe systems are based on the simple BBOP interactive keyframe approach to

animation with added features that ease the animation process. At their core, they all have features of BBOP (some copied, some developed independently), including hierarchical skeleton structures, real-time interactive update of transformation values, interpolation of keyframes in channels so that different joints can have different keys in different frames, choice of **interpolation** functions such as linear, cubic, ease-in and ease-out, immediate playback and an interpolation editor.

In general, however, scripted systems still are best for repeated or easily describable movements, but require programming skills beyond the capabilities of most artists, especially as movements become more complex. Scripting expressive characters, for example, is extremely difficult, not to mention unnatural for an artist. Interactive keyframe systems are just the opposite. They allow artists to interact directly with the objects and figures within a familiar conceptual framework. But they become inefficient or tedious to use for mechanical or complex algorithmic motion. Because they are more easily used by artists, the interactive keyframe approach has won in the commercial software market. Curiously enough, as animators are becoming more sophisticated in their use of computer animation, scripting capabilities are beginning to reappear in keyframe systems. The newest version of Wavefront|Alias' MAYA animation system has a built-in scripting capability that allows animators to tie actions to events, define movement as functions of other movements, create macros and more.

Early 3D animation systems mostly dealt with simple forward **kinematics** of jointed bodies, however inverse kinematics can also be an important element in an animation toolkit. By moving just a hand or a foot, the animator can position an entire limb. Michael Girard [at Ohio State University] built a sophisticated inverse kinematic animation system for his Ph.D. thesis [9] which was used for producing very graceful human body movement in his 1989 film Eurhythmy. He later commercialized his system as a 3D Studio MAX plug-in, Biped (part of the Character Studio package), where legged locomotion such as walks, runs, jumps and skips can be animated by placing footprints. His inverse kinematic algorithms compute the motions of the figure that cause it to follow the footprints.

When Softimage was first released, it was the first commercial system to feature an inverse kinematics capability (although in a simplified form). That feature helped greatly in selling the new system. Now, almost all 3D animation systems have some form of inverse kinematic capabilities.

Dynamics is also an important tool for realistic animation. Jane Wilhelms was one of the first to demonstrate the use of dynamics to control an animated character [31]. Since then, James K. Hahn (Ohio State), David Baraff and Michael McKenna [12, 2, 17] have all described robust dynamics for computer animation. Yet it is only in the past few years that the major commercial systems are incorporating dynamics into their software. The problems they are facing are how to integrate dynamic controls, inverse kinematic controls, and forward kinematic controls within the same system, and presenting and resolving clearly the potentially conflicting constraints each puts on the animated elements.

Kinematics and dynamics deal with jointed skeletal structures. However, not all animation is skeletal. A face, for example, is a single surface with complex deformations. Fred Parke was the first to attack this problem [20] with a parametric facial model. Using parameters to describe key aspects of facial form, such as mouth shape, eye shape and cheek height, and then animating these parameters, he was able to simulate the motions of a human face as a single surface. The system was used by NYIT in a music video for the group Kraftwerk, but never commercialized.

Years later, **Philippe Bergeron** and Pierre Lachapelle digitized plaster models of several dozen expressions of a face, and created a system to interpolate between several of these target expressions at once for their 1985 short film *Tony de Peltrie* [3]. The result was a rubbery-faced character with a wide range of human expression. Rudimentary implementations of this technique of 3D object interpolation (or 3D target morphing) were incorporated into Softimage and Alias|Wavefront systems a few years ago, and are being improved for the latest versions of their software. 3D target morphing is also the basis of Medialab's real-time character performance animation system.

Keith Waters developed an even more sophisticated facial animation system based on muscle activation influencing regions of the face model [30]. This system produces very realistic facial motion and can be controlled by high-level commands to the muscle groups. His methods have not been commercialized, but simpler versions are used in some optical facial motion capture systems.

There follow a whole host of bits and pieces to animate particular effects. Some of these have been integrated into commercial animation systems. Others are used exclusively by the companies that developed them, while still others have just seen proof of concept and await a plug-in or incorporation into a more complete system.

The most influential of these (and perhaps not really in the bits and pieces category) is Bill Reeve's particle systems [22]. Reeves developed a method of using controlled random streams of particles to simulate fire, grass, sparks, fluids and a whole host of other natural phenomena. First used in the movie Star Trek II, particle systems are easy to implement and quickly appeared in many amateur, academic and professional CG animations, most notably Particle Dreams in 1988 by Karl Sims. Commercial animation systems took a little longer to incorporate the technique into their established structures, but today everyone has it in some form or another.

Other animation techniques for specific effects in the literature include (but by no means are limited to) automated gaits (walking, running, jumping, etc.) [5, 13], flocking behaviors [24, 1], fluid flow [14], waves [7, 21], smoke [27], sand [15], flexible objects [29], snakes [18], cloth [29] and many more.

As was already mentioned, the most difficult animation is character animation, particularly human character animation. In a quest for more realistic motion, people have looked towards directly recording the motions of a human performer. Lee Harrison III in the 1960s was only the first of many to use this concept. In 1983 Ginsberg and Maxwell [8] presented an animation system using a series of flashing LEDs attached to a performer. A set of cameras triangulated the LEDs' positions, returning a set of 3D points in real time. The system was used soon after to animate a CG television host in Japan. However motion capture systems and graphics computers were just not fast enough then for the real-time demands of performance animation.

When they did begin to become fast enough, around 1988 with the introduction of the Silicon Graphics 4D workstations, deGraf/Wahrman and Pacific Data Images both developed mechanical controllers (also known as waldos) to drive CG animated characters — deGraff/Wahrman for CG facial animation for a special SIGGRAPH presentation and for the film Robocop II, and PDI for a CG character for a Jim Henson television series and several other projects. For various reasons the technology and market were not ready and the systems were rarely exploited after their initial use.

Then, in the early 90s, SimGraphics, Medialab (Paris) and Brad deGraf (with Colossal Pictures and later Protozoa) all independently developed systems that allowed live performers to control the actions of a CG character in real time. These systems allowed characters to be animated live, as well as for later rendering. The results, particularly

with Medialab's system, are characters that have very lifelike and believable movements. Animation can be generated quickly by actors and puppeteers under the control of a director who has immediate feedback from the real-time version of the character. All three systems have survived their initial versions and applications, and continue to be successfully used in commercial projects.

At first, these systems existed on their own and were not integrated into other commercial CG systems. Animation done in a keyframe system could not easily be mixed with animation performed in a real-time system. As time has passed, both the real-time systems and the keyframe systems have evolved, and now many keyframe systems have provisions for real-time input and the real-time systems import and export keyframe animation curves.

Performance animation has become very popular recently and at the SIGGRAPH 97 trade show, no less than seven companies demonstrated performance animation systems.

Similar to performance animation, but without the real-time feedback, are motion capture systems. These are generally optical systems that use reflective markers on the human performer. During the performance, multiple cameras calculate the 3D positions of each marker, tracking it through space and time. An off-line process matches these markers to positions on a CG skeleton, duplicating the performed motion. Although there are problems with losing markers due to temporary occlusions and the animation matching process can be very labor-intensive, motion capture permits an accurate rendering of human body motion, particularly when trying to simulate the motion of a particular performer as Digital Domain did with Michael Jackson's 1997 music video, Ghosts.

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For an historical overview of the development of animation systems in general, see the summary of Steve May's 1998 PhD dissertation. *https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/09/smay-animation.pdf*

For the entire dissertation,
Encapsulated Models: Procedural Representations for Computer Animation.
Stephen F. May. PhD thesis, The Ohio State University, March 1998.
go to

http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.128.1095&rep=rep1&type=pdf

8.2 Wavefront Technologies



Portions of the following history of Wavefront was extracted from corporate historical accounts.



Wavefront Logo

In 1984, Wavefront Technologies was founded in Santa Barbara, California by Mark Sylvester, Larry Barels and Bill Kovacs, who wanted to produce computer graphics for television commercials and movies. Since off-the-shelf software was not available at the time, the founders adapted their business plan to develop and market their own graphic software. Contrary to anecdotes alluding to the founders' fondness for surfing California beaches, Wavefront was actually named after the term which describes the front edge of a wave of light.

During the first year, the company's production department, headed by John Grower (later head of Santa Barbara Studios) created opening graphics for Showtime, BRAVO and the National Geographic Explorer, allowing the new and first software product, *Preview*, to be modified to meet the needs of animators. *Preview* was then shipped to Universal Studios to be used on the television series Knight Rider and to Lamb and Company for use in **pre-visualizing** and controlling a motion camera rig.

In 1985 Wavefront exhibited at its first trade show, NCGA in Dallas, Texas, and participated in the SGI booth (with Alias sitting at the next table) and sold *Preview* to NBC Television in New York, Electronic Arts (London), Video Paint Brush (Australia), Failure Analysis (Mountain View) and NASA (Houston).

In 1987 Wavefront established an office in Brussels. The Belgian government became an investor and provided capital for the purchase by Wavefront of Abel Image Research (AIR) in 1988. Ironically, in many ways AIR (founded in early 1987) was the predecessor of Wavefront, since founder Bill Kovacs was a principal software

developer at Abel. This purchase dramatically increased its penetration into the Japanese market. Another irony of this is that one of the largest customers in Japan is Omnibus, who was responsible for buying and closing the Abel operation through the Omnibus "**DOA**" fiasco of 1987.

In 1988 Wavefront entered the desktop market with the *Personal Visualizer*. This software gave CAD users a point and click interface to high-end photo realistic rendering. Co-developed with Silicon Graphics, this product was eventually ported to Sun, IBM, HP, Tektronics, DEC and Sony. The strategy was to bundle the software with every system sold, then follow with module sales into the installed base. In 1989, they continued this thrust into markets beyond the entertainment industry, moving into the scientific community with the *Data Visualizer* software. This was a highly flexible product for industrial design applications worldwide and built upon Wavefront's reputation for open systems and fast graphics interaction.

In 1990, Wavefront achieved further expansion in Asia. CSK, exclusive reseller of IBM hardware in Japan, became part owner of Wavefront Japan. In 1991, Wavefront launched the *Composer* product, which provided advanced image production for creating, enhancing and recording high-impact presentations. *Composer* would become a standard for professional 2D and 3D compositing and special effects in the feature film and broadcast/video arenas. In 1992 they introduced two new products that would have dramatic impact on the entertainment and effects industry. *Kinemation*, with SmartSkin™, was a complete 3D character animation system for creating synthetic actors with natural motion and muscle behavior. *Dynamation* was developed by Jim Hourihan (Jim received his first Academy Award for Technical Achievement for the creation of *Dynamation*), and was a powerful 3D animation tool for interactively creating and modifying realistic, natural images of dynamic events. The resulting images came from the seamless blending of behavioral data and user-specified information describing shape, color and motion. According to Hourihan, *Dynamation* was developed from a program called '***willy***' that was used by a number of LA effects houses for special effects.

In 1993 Wavefront acquired Thomson Digital Images of France (founded in 1984). TDI had innovated in the area of NURBS modeling and interactive rendering and had extensive distribution channels in Europe and Asia. Originally a partner with IBM, TDI also established a commercial production arm, which would later merge with Sogitec to become Ex Machina. TDI's main software product was TDI Explore, a tool suite that included 3Design for modeling, Anim for animation, and Interactive Photorealistic Renderer (IPR) for rendering. (Note: Alias Maya is the result of the merger of the three packages: Wavefront's Advanced Visualizer, Alias's Power Animator, and TDI's Explore.)

In 1994, they partnered with Atari to develop and market GameWare, which became the exclusive game graphics and animation development software for the Atari Jaguar system. Under the terms of the agreement, Atari used GameWare for internal content creation and advised third-party developers to use GameWare as the image and geometry-authoring tool for the new 64-bit Jaguar game system.

Dream Quest Images created over 90 visual effects sequences for the 1994 *Crimson Tide* movie using Dynamation and Composer. "Since most audience members have never experienced the environment of a nuclear submarine, it was critical to deliver a realistic virtual experience for the viewer," said Mitch Dobrowner, digital department manager at Dream Quest. Wavefront software was also used for other blockbusters, including *Outbreak, Aladdin, True Lies and Stargate*.

In 1995, Wavefront (who was valued on the market at $119M with revenues of $24M) was acquired by Silicon

Graphics, along with Alias, for $500M to form the new Alias/Wavefront venture. It is stated that the purchase was in response to the success in the CG industry of the Canadian company Softimage.

A 1998 article titled *The First Wave: The Origins of Wavefront Software* is archived at Creative Planet and details the history of Wavefront Technologies.

Movie 8.1 Wavefront Demo



Wavefront Demo (1986)
https://www.youtube.com/watch?v=dolXi-3BcuA

Movie 8.2 Wavefront Demo (1988)
https://www.youtube.com/watch?v=2WU2Mckj15k

Movie 8.3 Wavefront Engineering Demo (1988)
https://www.youtube.com/watch?v=0NY4dXRA3BM

Movie 8.4 *Sample animations from the 1993 Wavefront Technologies Users Group. This is Part 2. Part1 of this compilation can be seen at*

http://www.youtube.com/watch?v=3PBH0tvZCaE

Note: Because of licensing restrictions from Sony Music Entertainment, the entire videos cannot be viewed on a mobile device. The following links can be used to view them on a desktop computer

Part 1 – http://www.youtube.com/watch?v=3PBH0tvZCaE

Part 2 – http://www.youtube.com/watch?v=p2qivAkzKZY

The First Wave: The Origins of Wavefront Software Creative Planet Network, February 2012.

The following is excerpted from a memorial article for Bill Kovacs from Animation World Network (June 2006)

> Bill Kovacs, who co-founded Wavefront Technologies, earned a 1997 Academy Award for science and engineering innovations and who worked as a programmer on TRON, passed away last Tuesday at his home in Camarillo, California. Kovacs, who was 56, died of a stroke in his sleep brought on by a cerebral hemorrhage.
>
> In 1984, Kovacs co-founded software company Wavefront Technologies in Santa Barbara, California. He was the company's cto until he left in 1994, when the company went public. In 1995, Silicon Graphics acquired

Wavefront. Later, both firms merged with Toronto-based Alias Research to form Alias Wavefront. Wavefront's software was combined with code from Alias Research to create Maya software. Maya, of course, is now a leading computer animation tool owned by Autodesk.

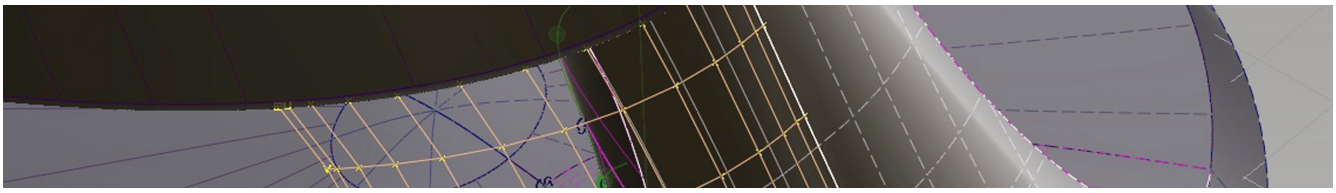
In 1997, Kovacs shared the Scientific and Engineering Academy Award with Roy Hall. The two were recognized for their work in developing Wavefront's Advanced Visualizer computer graphics system.

At Robert Abel & Associates, Kovacs was a programmer for Disney's 1982 feature, TRON, which incorporated early computer animation and paved the away for the 3D revolution.

After working for Wavefront, Kovacs was a consultant to game manufacturer Electronic Arts and Hollywood digital production company RezN8. He also was a founding partner in software startup Instant Effects.

Kovacs helped develop the School of Film and Television at Loyola Marymount University, and was its first visiting artist for technology. Recently, he lectured at UCLA and the Academy of Art University in San Francisco, where he was on the Presidential Advisory Board.

8.3 Alias Research



Portions of the following history of Alias was extracted from corporate historical accounts.

Alias Logo

The founders of Alias, Stephen Bingham, Nigel McGrath, Susan McKenna and David Springer wanted to create an easy-to-use software package to produce realistic 3D video animation for the advertising industry and post-production houses. In 1983 they came up with the idea for a software development effort to achieve this goal. Springer was teaching computer programming for designers at Sheridan College. A rare combination of artist and computer programmer, he had been working independently on software which, by coincidence, resembled McKenna's and Bingham's idea. They quickly brought him on board, and he supervised the project that involved 300,000 lines of code written in the C programming language.

Bingham was an unlikely high-tech tycoon. Lacking any formal engineering or technical training, he obtained a Master's degree in Canadian studies from Ottawa's Carleton University. He then served as the director of the city's National Film Theatre from 1980 to 1983, which allowed him to indulge in his love for movies and animation. It was a visit to Hollywood director George Lucas's renowned Industrial Light & Magic animation studios in California that inspired Bingham to form his own animation company.

Susan McKenna first got the computer itch in high school where she took Fortran. The youngest of five children, she was the first woman in the family to want to enter business with an ambition for adventure and risk. Stephen Bingham and Susan McKenna met at Carleton University in Ottawa. She spent 2 1/2 years doing administrative work in audio-video production, raising capital, writing proposals and arranging funding. McKenna approached Nigel McGrath, knowing his reputation in the industry for mixing high technology and graphic design. After high school, McGrath freelanced as a graphic artist and started McGrath & Associates in 1980 to serve major corporate clients. He kept the company while starting Alias, lending the new firm $500,000 worth of computer graphics equipment.

In 1983 they were able to obtain a $61,000 grant from the National Research Council, which, combined with the limited funds of the founders, allowed work to begin on the development of that first code, a huge undertaking

that required 36 man-years of programming or 18 programmers writing for two years. Other financial support was gained from the federal government through Scientific Research Tax Credits (SRTCs). The first office, with a rent of $150/month, was located in Toronto in a renovated elevator shaft in the building that would later become the home of CITY-TV.”There were strange drafts, cold air would mysteriously fill the room, like we were in a scene from Spielberg’s *Poltergeist*,” said Susan McKenna. In 1984 the group decided on the name Alias for their new venture. “I think it was Steve who came up with the name Alias, while we were sitting in a Detroit restaurant during SIGGRAPH”, says Nigel McGrath. “You know what we need is an alias”, Steve said. “We all clicked at that point because the only paying job we had at the time was for Dave Springer to write an anti-aliasing program for a few users at SGI. That’s where the name came from”.

Alias unveiled Alias/1 at SIGGRAPH 85 in San Francisco. Alias/1 was unique because it was based on cardinal splines, producing much smoother and realistic lines or surfaces than polygonal lines. The first sale of Alias/1 was to Post Effects in Chicago followed by Editel in New York and Production Masters in Pittsburgh. Also in 1985, Alias signed a landmark deal with GM to design a system incorporating **NURBS** (non-uniform rational basis spline) technology compatible with GM’s spline based CAD (computer-aided design) system. This was the beginning of a business relationship that is still thriving today.

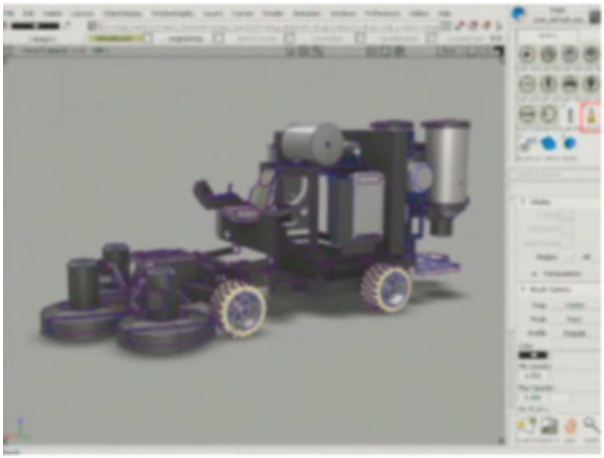
Later that year, the Alias founders approached Silicon Graphics Inc. and suggested that SGIs super-microcomputer could be used for graphic design. Until that point, SGI’s hardware had only been used for computer-aided design and computer-aided manufacturing (CAD/CAM). SGI spotted the potential for selling a computer every time Alias sold its software. These new research and development efforts required additional capital to finance the effort. Now that Alias had a big client (GM) more or less in hand, the risk was less in the eyes of potential investors. Early in 1986, Crownx, a venture capital company associated with Crown Life, invested $1.2 million for a 20% stake in Alias.

Although most of Alias sales had been to small production houses, Kraft and Motorola were added to the new client roster in 1986. Moreover, Alias managed to beat two American bidders to supply the $400,000 computer-controlled TV type equipment that would let the world watch what the Hubble Telescope could see from space. 1986 also saw the introduction of the second generation Alias/2. It had the basis spline geometry that led to the creation of the term **CAID** (computer- aided industrial design) and a whole new market. In 1987 Alias’ staff increased to 70 people with the opening of three U.S. sales offices. Concurrently, new venture capital was received from US Investors Greylock and TA Associates.

Exclusive rights to sell Alias/2 into the entertainment markets were passed in 1988 to a single worldwide reseller BTS (now Phillips BTS) who sold Alias/2 with their Pixelerator rendering machine. The Alias sales focus could remain exclusively on design opportunities, where most sales were direct except for 8 resellers in Asia. Alias boasts an impressive list of customers including Timex, Reebok. Oakley, Kenner, BMW, GM, Honda, Volvo, Apple, GE, Motorola, Sony, Industrial Light and Magic, Broadway Video and The Moving Picture Company.

Steve Williams (ex-Alias) went to ILM to help create the pseudopod creature in the 1989 movie *The Abyss*. Alias 2.4.2 was chosen by Williams for modeling because it was patch-based (B-splines) instead of polygons. The software ran on SGI 4D/70G and 4D/80GT workstations. *The Abyss* was hailed by the film industry to be one of the most technologically advanced and difficult motion pictures ever filmed. This was proven when ILM received an Academy Award for Best Visual Effects for *The Abyss*. For the first time, Alias’ software got high-profile recognition in movie animation.

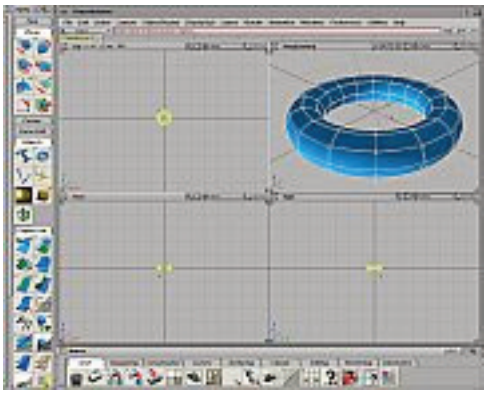
In 1989 one of Alias' most high profile industrial clients, Honda was so pleased with Alias technology that it assisted with the development of the newest version of ALIAS/2. Visiting from Japan, a Honda executive commented: "Thanks to Alias' software, we have 20 people doing the work of 200." The 1989 Honda Accord became the first car made by a foreign manufacturer to head the U.S. bestseller list. Many of Honda's cars, like those of BMW and Volvo, were designed on 3D software created by Alias.



Alias Screenshot

Alias raised about US$35 million in their 1990 initial public offering of 2.5 million shares. "U.S. investors understand the value of the investment better. Canadians focus on the trouble with tech stocks and not the money that's been made trading those stocks," said founder Bingham. 1990 also saw the introduction of its third generation software, branded Studio for industrial design and PowerAnimator for the entertainment market.

That same year Alias client ILM reaped the highest honors for Best Visual Effects at the Academy Awards. PowerAnimator was used to create Arnold Schwarzenegger's foe, the chromium killer cyborg in *The Terminator*. Strangely enough, Schwarzeneger, who reportedly earned $12 million for that movie, was not the highest paid actor. The liquid metal man's salary worked out to about $460,000 per minute compared to $200,000 per minute for Schwarzeneger.



Alias Modeling Session Screenshot

IBM unveiled a new line of workstations n 1990 and promoted Alias software among sales staff and customers. "Alias is the best worldwide in visualization and animation," said IBM Canada President, John Thompson. Rob Burgess, (now Chairman and CEO of Macromedia) was appointed president of Alias in 1991 with the mission to take the company to the next level of growth. Burgess announced a 3 year strategic alliance with SGI. He also seized the opportunity to purchase the Spacemaker technology and launched UpFront, a low-cost 3D Mac and Windows based package for architects. Alias achieved a major coup by impressing Bill Gates, who mentioned Upfront during a major Microsoft conference as a particularly innovative application under Windows. "In the graphics area, I picked Upfront from Alias Research. It is really an incredible tool for making sure the design is exactly right," said the Chairman of Microsoft. This project would pave the way for the development of Sketch!, positioned as a tool for graphic artists who wanted to do more realistic 3D work than could be done with Adobe Illustrator.

Alias continued to broaden its products range with the acquisition of Sonata, a high-end 3D architectural design and presentation system, from T2 Solutions of the UK. This move gave Alias four divisions covering at least five distinct marketplaces:

- Alias Division (industrial design and entertainment),
- Style! Division (Upfront and Mac/Win for architects and Sketch! on Mac for illustrators),
- Sonata Division (architecture) and
- Full Color Division (pre-press and photo retouching).

Under the direction of Burgess, Alias pushed toward its dominance of the entertainment and design markets. In the Spring of 1992, new animation features, primarily an IK (inverse kinematics) solver, were included in the fourth version of PowerAnimator. It was used to create many of the effects in Batman Returns which provided a great testimonial for Alias' return to the entertainment arena at SIGGRAPH 92. They also showed that they hadn't forgotten their design market when they introduced AutoStudio, a package specifically tailored to automotive designers. This continues Alias' focus on the transportation design sub-segment that had done very well for the company.

In 1993 Alias started the development of a new entertainment software, later known as Maya which would become the industry's most important animation tool. Steven Spielberg chose Industrial Light & Magic to provide the visual effects in 1993's *Jurassic Park*. In turn the animators at ILM picked PowerAnimator as the software of choice to model the huge prehistoric beasts. They delivered the very real looking dinosaurs with PowerAnimator and reaped the Oscar for Best Visual Effects.

Alias worked in close cooperation with Ford to develop StudioPaint, a high-end paint package designed for automotive sketching and rendering with real-time airbrushes. Rollerblade decided to purchase Alias Studio as the CAID tool of choice for their skate design after extensive benchmark testing. "Alias makes it much easier for our designers to sculpt the complex surfaces required to achieve innovative designs while meeting the constraints required for foot comfort," explained Todd J. Olson, senior industrial designer for Rollerblade Inc. Alias signed a landmark agreement with Nintendo in 1994 to be the key software tools provider. PowerAnimator was used to create *Donkey Kong Country* for Nintendo. As a result of these relationships, Alias dominated the games segment with the largest share of revenue. Alias made headlines in the Globe & Mail for helping car companies save both time and money with its industrial design software. "Detroit's auto makers are able to cut their vehicle's development time to three years from four-plus." Automotive and transportation design companies included: GM, Ford, BMW, Volvo, Honda, Toyota, Fiat, Hyundai, Isuzu, Nissan, Renault, Saab, Subaru, Caterpillar, Kenworth and Mitsubishi. In 1994, Ford became the largest StudioPaint installation in the world when it purchase StudioPaint for its revolutionary Global Studio design facility. StudioPaint allowed designers to create "digital concept sketches" using real-time pencils and airbrushes, and "digital facelift" of existing designs using retouching and real-time image transformation tools.

Alias' profits soared in 1994, primarily because of success in the movie industry. They reported a profit increase of 181% for the second quarter of Fiscal '95. Alias' PowerAnimator was used in five of the biggest movies in the summer of 1994: *Forrest Gump, The Mask, Speed, The Flintstones, True Lies and Star Trek: The Next Generation "A Final Unity"*. Alias customers in special effects included the most prominent studios, such as Industrial Light & Magic, Angel Studios, Digital Domain, Dream Quest Images, Cinesite, Metrolight Studios, Pixar, Sony Pictures Imageworks, Video Image, The Walt Disney Company and Warner Brothers.

Movie 8.5 Alias 3D Software



https://www.youtube.com/watch?v=pCVUOxvQWaU

Bill Buxton, Alias' Chief Scientist in 1994, has a collection of Alias videos on his website at *http://billbuxton.com/buxtonAliasVideos.html*

8.4 Alias/Wavefront





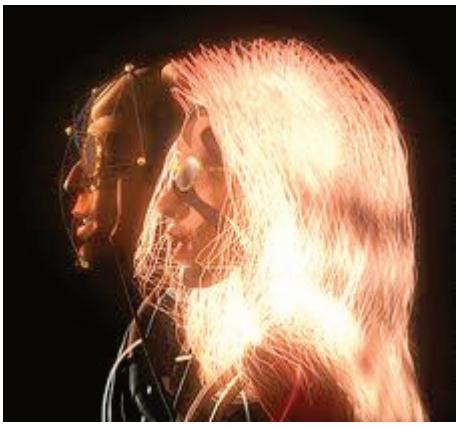
Alias/Wavefront Logo

The corporate history of Wavefront Technologies changed dramatically in 1995, with the merger of Alias and Wavefront. On February 7, 1995, Wavefront Technologies, Inc., Silicon Graphics, Inc. and Alias Research, Inc. announced that they entered into definitive merger agreements. The new company's mission was to focus on developing the world's most advanced tools for the creation of digital content. "We created digital skin, then [Alias] did; now they've created digital hair and we're working on digital clothing. With both of us working together, we can attack the bigger technical problems instead of duplicating work," said Mark Sylvester, cofounder of Wavefront.

In April, 2003 the company was renamed Alias.

Following are some important events in the continuing history of the new company:

- 1995 – Alias used in films including *Toy Story, Pocahontas, Casper and Golden Eye, and Batman Forever*.
- 1995 – Sega Interactive uses PowerAnimator to create Stars Wars Arcade.
- 1996 – Alias|Wavefront sets up new offices in Hong Kong, Singapore, Malaysia and Australia.
- 1996 – Alias|Wavefront's Chris Landreth is nominated for an Academy Award for the short film, *The End*, to test new features added to the development of Maya including motion capture, **facial animation** and hair. (See Section 19.8 for more on Landreth.)

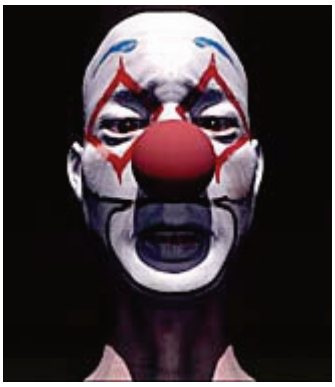


Scene from Landreth Film

- 1997- Alias|Wavefront reports a 44% increase in its sales over the previous year in industrial design sales and attributes it to the delivery of new advances in CAID technology as well as the release of new product versions: AliasStudio 8.5, Alias AutoStudio 8.5 and Alias Designer 8.5 Its existing customers include Philips design, Daewoo(UK), Rubbermaid, BMW, Renault, Honda and Audi.
- 1997 – Ford Motor Company chooses AliasStudio to standardize its existing computer-aided industrial design processes. Valued at over $4 million in sales and services, this is one of the largest sales in the company history. As a significant step in the implementation of Ford's C3P program, the purchase of AutoStudio represents the automaker's decision to replace its existing computer-aided industrial design processes and standardize on Alias|Wavefront software.
- 1997 – Launch of Composer 4.5 featuring motion blur, lens distortion and time warp technology. Effects created with Composer are featured in many Hollywood films including *Mars Attacks, Dante's Peak, Casino, Broken Arrow and Waterworld*.
- 1998 – Alias|Wavefront introduces its new 3D flagship product Maya. Maya is a leader in the industry in the following key areas: bringing characters to life, explosive visual effect and system architecture. Representatives from Blue Sky/ VIFX, Cinesite, Dream Pictures Studio, Dream Quest Images, GLC Productions, Kleiser-Walczak, Rhonda Graphics, Square, Santa Barbara Studios and Imagination Plantation were among many of the BETA customers to support Maya. Industrial Light & Magic makes a strategic investment in purchasing enough seats of Maya to give technical directors and artists throughout its digital production departments extensive use of Alias/ Wavefront's most advanced 3D software.

Maya Logo

- 1998 – Academy Award Plaques are awarded to Bill Kovacs and Roy Hall of Wavefront for the development of Advanced Visualizer. Certificates are awarded to Jim Keating, Michael Warhman and Richard Hollander for their contribution to the development of the Advanced Visualizer. Plaques are also awarded to John Gibson, Rob Krieger, Milan Novacek, Glen Ozymok and Dave Springer for PowerAnimator. Advanced Visualizer is acknowledged by the Academy as the first commercial software package for modeling, animating and rendering adopted into widespread use to create digital images with sufficient quality for motion pictures.



Scene from Bingo

- 1998 – Chris Landreth produces *Bingo*, an animated short, to run Maya through its paces, pushing the product to its limits and making sure it lives up to the industry's expectations. In *Bingo*, Chris Landreth introduces a cast of animated characters who are human-like and disturbingly freakish. *Bingo* garners international attention and is recognized at film festivals around the world.
- 1999 – Alias|Wavefront announces industrial design software Studio and DesignStudio for the Windows NT platform. Studio and DesignStudio are the choice of major automotive companies such as BMW, Fiat, Ford, Honda, Italdesign, and Renault.
- 1999 – Maya Complete incorporates all of the tools and features for world class animation on both IRIX and NT platforms. Maya Complete has been developed to provide state-of-the-art 3D solutions for a more broader, professional market. It includes Alias|Wavefront's award winning 3D modeling, rendering, and animation technology.
- 1999 – Maya Unlimited, the new graphics production suite for high-end film and video industry is introduced. Maya Unlimited incorporates all of Maya Complete elements plus Maya Cloth, Maya Fur, Maya Live, and Maya Power Modeling. It addresses the unique needs of high-end production houses, by providing them with tools that will help solve complex problems.
- 1999 – A subset of Maya Complete, Maya Builder was optimized to address the specific needs of level designers and programmers in the game and interactive title development community.
- 1999 – Alias|Wavefront announces at SIGGRAPH 99 that Maya has been used by Industrial Light & Magic (ILM) in the summer blockbusters *Star Wars: Episode I "The Phantom Menace," The Mummy, and Wild, Wild West*.
- 2000 – Alias |Wavefront includes a universal rendering policy for the release of Maya 3 that enables Maya Complete and Maya Unlimited customers to "float" the Maya Batch Renderer across any number of machines on Windows NT, IRIX and Linux platforms.
- 2000 – Alias|Wavefront announces its intentions in bringing Maya to the Apple® Mac® OS X platform.
- 2000 – Alias|Wavefront was rewarded with its largest, single software agreement ever from General Motors. The primary software provided is AutoStudio, SurfaceStudio, and StudioPaint
- 2000 – Maya was used to create the top four selling December 2000 titles for the PlayStation® 2 console. Electronic Arts (EA) Madden NFL 2001 led the list of top-sellers for December with SSX: Snowboard Supercross (EA) second, Tekken Tag Tournament (Namco) third, and NHL 2001 (EA) fourth. All three nominees for Best Visual Effects in a motion picture used Alias |Wavefront software. *The Matrix*, (Manex) *Stuart Little*, (Sony) and *Star Wars Episode I: The Phantom Menace*, (ILM) were rewarded with nominations for the ground breaking work in film. *The Matrix* went home with the Oscar.
- 2001 – In March, Alias|Wavefront ships entire suite of Maya 3D software products to the Red Hat™ Linux® operating system.
- 2001 – Alias|Wavefront expansion program continues with the release of version of its 3D computer-aided industrial design (CAID) software family, StudioTools, made specifically for the Hewlett-Packard® HP-UX® operating system.

- 2001 – Maya software played a pivotal role in allowing Square® USA to create a 23-digital-person cast for the much anticipated summer film *Final Fantasy*.
- 2001 – The recently unveiled mental ray® for Maya technology ships.

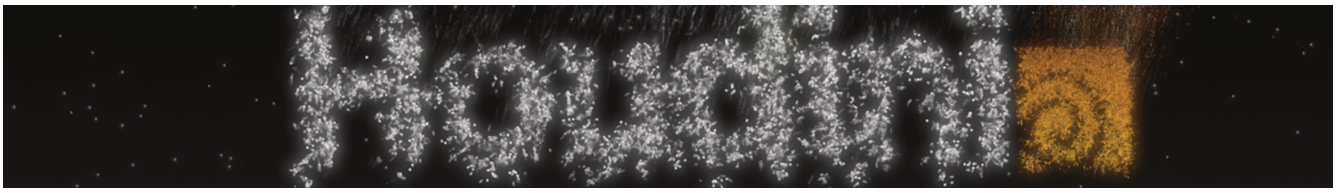
> NOTE: In October of 2005 Autodesk announced that it had signed an agreement to acquire Alias. In January of 2006, the acquisition was finalized for US$197M in cash.

Movie 8.6 Alias/Wavefront Maya



1998 Alias/Wavefront Maya demo reel
https://www.youtube.com/watch?v=pHFLapfliN8

8.5 Side Effects

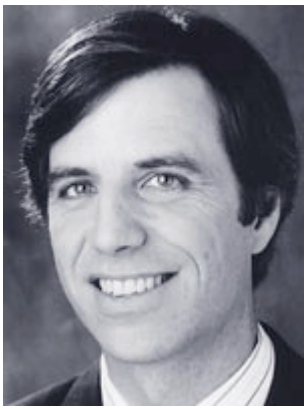


The following history of Side Effects was extracted from? http://www.sidefx.com

Side Effects Logo

Based in Toronto, Canada, Side Effects Software was established in 1987 by Kim Davidson and Greg Hermanovic, an animation director and programmer respectively. This duo founded their new production/software company on a 3D animation package, PRISMS, which they had acquired from their former employer Omnibus. Side Effects Software developed this procedural modeling and motion product into a high-end, tightly-integrated 2D/3D animation software which would incorporate a number of technological breakthroughs.

Prior to co-founding Side Effects, Hermanovic worked as the Director of Research at Omnibus. When the company went bankrupt in 1987 he teamed up with Director of Animation, Kim Davidson, to buy the rights to the company's PRISMS 3D animation software code. The two partners incorporated Side Effects and set out both to provide content for the Toronto broadcast market and to continue developing PRISMS. In the time that has elapsed since then, the company has turned its attention fully toward development and grown to become one of the world's leading 3D animation software providers. Throughout his career with Side Effects Software, Hermanovic was the driving force behind the implementation of such cutting edge innovations as: procedural modeling, morphing and CHOPs (nonlinear, nondestructive motion editing). Hermanovic was experimenting with C-music and algorithmic composition as far back as 1982. In February 2000, he founded Derivative, Inc. to bring professional special-effects technology to the VJ (visual jockey) scene. Derivative produces innovative tools for designing and performing interactive 3D artworks and live visuals.

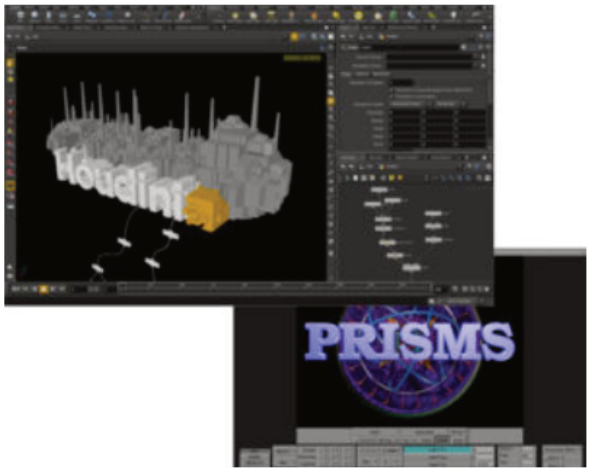


Kim Davidson

Davidson also owned Catapult Productions, which was founded in 1992 for the purpose of creating entertainment using computer character animation. Their specialty was children's content. He graduated from the University of Waterloo with degrees in Architecture and Mathematics and did extensive graphics programming since 1980. He was the animation director at two large commercial animation houses in Toronto from 1986-1990 and worked on or directed over 300 hundred computer animated pieces in that time.

PRISMS was used extensively to create visual effects for broadcast and feature films in the late '80s and '90s. Early film projects included: *Apollo 13; Twister; The Fifth Element, Independence Day and Titanic* – the last two having won an Academy Award for Best Visual Effects. The company would continue to develop and support PRISMS until version 7.1 in 1998.

At SIGGRAPH 1996 Side Effects Software introduced Houdini: a next-generation 3D package that would prove to be more sophisticated and artist-friendly than its predecessor. From the following year to the present Houdini has been honored with numerous awards including an annual CGW Innovation Award. Houdini is used around the world to develop cutting edge 3D animation in the film, broadcast and gaming industries. To better serve the needs of its West Coast clients, Side Effects opened a Santa Monica, California-based office in 1995. The positive results can be seen in such recent hit movies such as *Fight Club*, *Hollow Man* and *X-Men* as well as Academy Award winners: *What Dreams May Come* and The *Matrix*.



Houdini/Prisms



Davidson, Hermanovic, Breslin and Elendt

In 1998 the Academy of Motion Pictures Arts and Sciences presented a Technical Achievement Award to Side Effects Software principals Kim Davidson and Greg Hermanovic and programmers Paul Breslin and Mark Elendt, for the development of the procedural modeling and animation components of PRISMS. ?Whether it's procedural motion/animation, or motion and audio editing, Side Effects Software has proven itself time and again to be an industry innovator. Some of the first breakthroughs that Side Effects included a high-end commercial 3D animation package:

- 1987 First to put a GUI on a **procedural modeling** system
- 1988 First to incorporate an expression language in the user interface
- 1989 First to add **metaballs**; First to have a polygon reduction tool (greduce)
- 1992 First to include a particle system; First to have a morphing package (mojo)

- 1993 First to have integrated motion capture (moca); First to include time frame sampling (tima)
- 1995 First to integrate all components (modeling, animation, rendering, compositing) into one executable;First to support NURBS, polygons, and Beziers as “equal citizens”
- 1998 First to have audio editing (Chops); First to put a GUI on a procedural particle system; First to introduce hierarchical splines
- 1999 First to port to the Linux O/S

Movie 8.7 Side Effects



Side Effects 20 Year Anniversary Reel (2007)
https://www.youtube.com/watch?v=ScrDrCN5b5s

8.6 Softimage

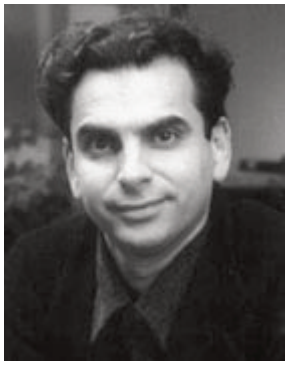


The following history of Softimage was extracted from corporate historical accounts.

SOFTIMAGE

SoftImage Logo

Softimage was founded in 1986 by National Film Board of Canada filmmaker **Daniel Langlois**. Langlois wanted to create animated films but was dissatisfied with the existing technology, which he felt was insufficient for his needs and designed to be used by computer scientists and technologists. His vision was a software company that addressed the creation of 3-D animation software not only for, but by artists. He felt that the concept marked a fundamental shift in how the industry viewed visual effects creation and generated a new breed of visual effects artists and animators. Other important members of the company included artist Char Davies (Davies left the company at the end of 1997 to pursue her artistic research separately.) Several important milestones that have influenced the industry have come from the “artist/ technology” vision:



Daniel Langlois

- the first integrated animation and effects system
- the first company to port animation tools to PC (NT)
- a broadening of integration to include post-production – with the release of Softimage|DS (now Avid|DS) and Softimage|XSI
- the expansion of animation and effects tool accessibility to the mass-markets in games and web content industries.

The first development effort for the startup company was the Softimage Creative Environment system, with “creative workflow and process integration”. In 1987 Langlois and engineers Richard Mercille and Laurent Lauzon began development of the company’s 3-D application software. Creative Environment 1.0 was launched

at SIGGRAPH 88. For the first time, all 3-D processes (modeling, animation, and rendering) were integrated. The system featured advanced tools and the first production-speed ray tracer. Creative Environment (eventually to be known as Softimage®|3D), became the standard animation solution in the industry.

Over the next several years the development team at Softimage released new versions of the 3-D software that included new innovations in image creation. For example, Creative Environment 1.65 added texture mapping (1989), Creative Environment 2.5 (1991) featured the Actor Module with IK (inverse kinematic), enveloping, and constraints, which enabled animators to combine conventional techniques (such as editing and keyframing) with these new capabilities. The system later won an award from the Academy of Motion Pictures Arts and Sciences. In 1990, the software was sold with an SGI workstation for $65,000.

Softimage went public on NASDAQ in 1992. That same year they started an aggressive acquisition effort, with the inclusion of the EDDIE® software and Painterly Effects. This provided a complete effects generation toolkit with advanced image processing tools for color correction, filtering, rotoscoping, morphing and painting. 1992 also saw an important corporate philosophy realized as Softimage opened their software to third-party developers. The channels performance capture technology offered a new dimension to CG character animation. The technology was used that year to create a memorable spot featuring 3-D dancing cars and gas pumps for Shell Oil.

1993 saw the second public offering of Softimage stock. The expansion of the creative product environment continued, with an agreement between Softimage and mental images that addressed rendering technology. Creative Environment 2.6 was released, featuring file management, metaclay, clusters, flock animation, weighted envelopes, channels, and an expansion of the open system policy. The Creative Toonz 2-D animation package automated the more tedious tasks involved in 2-D cel animation, such as inking-&-painting, while still maintaining the look of hand-drawn images and characters. With computer workstations advancing to be able to handle video, Softimage began the development of Digital Studio, as a step towards integrating the 2D/3D production pipeline. The power of a post-production environment in a software-based solution is consistent with Langlois' original vision for the company. mental ray®, an advanced stand-alone rendering system and Particles, an interactive particle animation system used to create natural phenomena such as clouds, snow, fire, etc. became part of the Softimage stable.

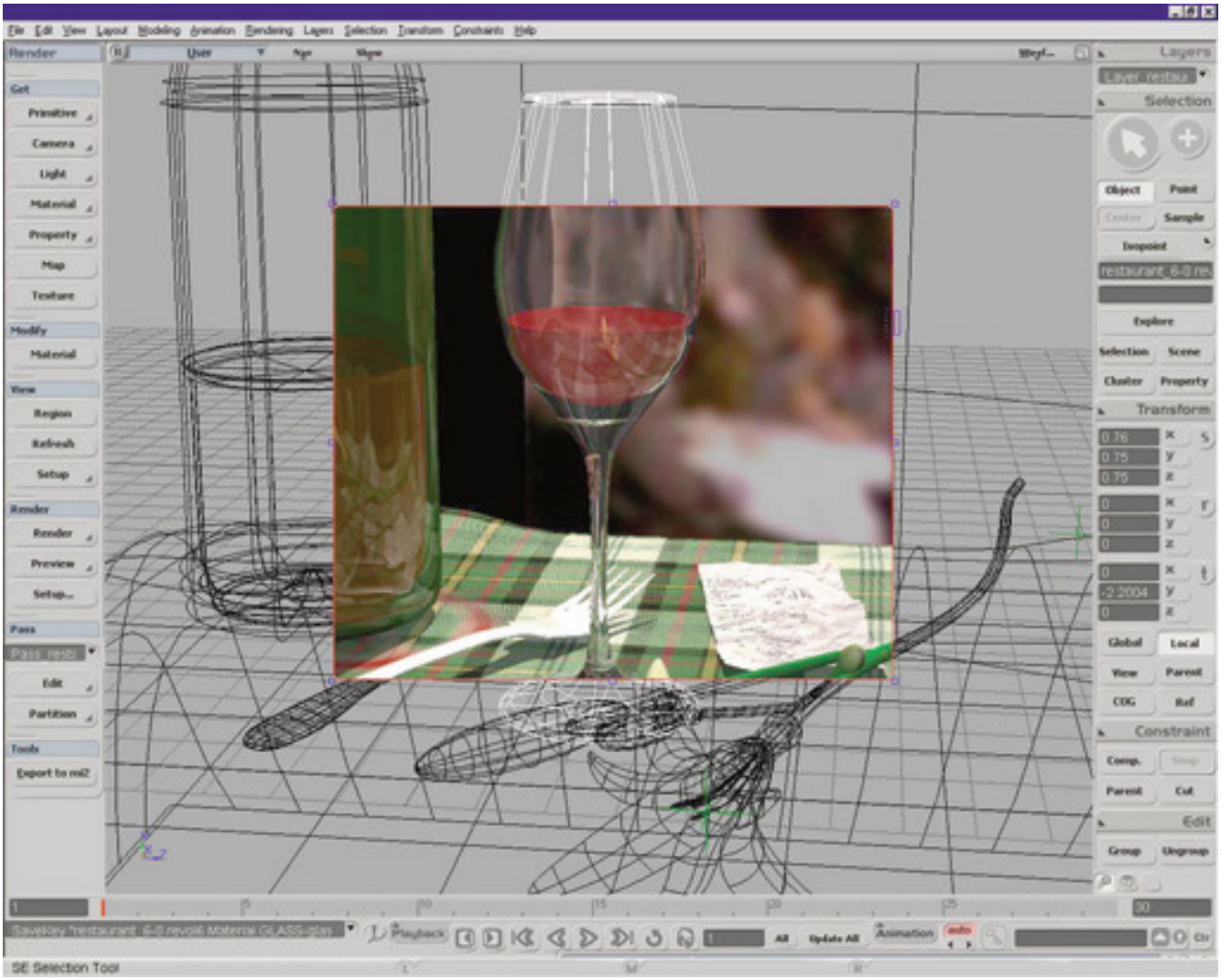
In 1994 Softimage merged with Microsoft Corporation, who acquired the company for $160M. Creative Environment 2.65 was released which featured expressions, dopesheet, ghost mode, and shape interpolation. The IDEAS (Interactive Developer's Entertainment Authoring Software) with ProPlay and ProPlay Plus was released. This software included Softimage Creative Environment, NURBS support, polygon and color reduction tools, dynamic simulations and inverse kinematics. It also Featured Eddie compositing, video-effects software, distributed ray tracer and the 3-D particles kit. Much of this system was aimed at the evolving game developer market.

Exploiting the power of the Pentium processor, Softimage developed the first high-end product on Irix and Windows NT in 1995. Creative Environment became Softimage|3D with a release that featured NURBS modeling, relational maudlin, trimming, instantiation, polygon reduction, tangent-to-path, constraint, Q-stretch, expressions, motion control, Actor, Particle, mental ray rendering, and Metaclay. (Langlois received a Scientific and Engineering Award from the Academy of Motion Pictures Arts and Sciences in 1998 for Actor). User-interface enhancements included hot-key remapping. The Softimage|3D "extreme" version included *Osmose*

(virtual reality), the new Virtual Theatre (featuring performance capture and real-time compositing), and mental ray. The Softimage|Toonz version 3.5 and Softimage|Eddie version 3.2 were also released.

The next two years saw the release of Softimage|3Dv 3.5 and Softimage|SDK Trance, “Sumatra”(code name) and RenderFarm, and Softimage|DS, one of the world’s most comprehensive nonlinear production systems (NLP™) for creating, editing and finishing videos. Softimage|DS enabled users to seamlessly integrate picture and audio editing, compositing, paint, image treatment, special effects, character generation and project management into one environment.

In 1998 Avid Technology, Inc. acquired Softimage for $247.9M (some reports indicate that the purchase price was closer to $300M). The two companies joined forces to develop the next generation tools for digital artists. The Animation Sequencer was introduced, and in 1999 “Sumatra” became the world’s first nonlinear animation editing system and merged all 3-D animation, editing, and composting tasks. In 2000 The Motion Factory, Inc., was acquired. The Fremont, CA-based company specialized in applications for the creation, delivery and playback of interactive rich 3-D media for character-driven games and the Web. In 2001 Softimage entered into an Xbox tools and middleware agreement with Microsoft, and they announced support for Linux. Softimage and Electric Rain collaborated to bring Flash, EPS, AI and SVG exports to Softimage|XSI customers. Michael Stojda became the Managing Director of the company in April of 2001 after working at Softimage and Avid and managing a wide range of effects, editing, and finishing products at both companies.



Screenshot composition from Softimage

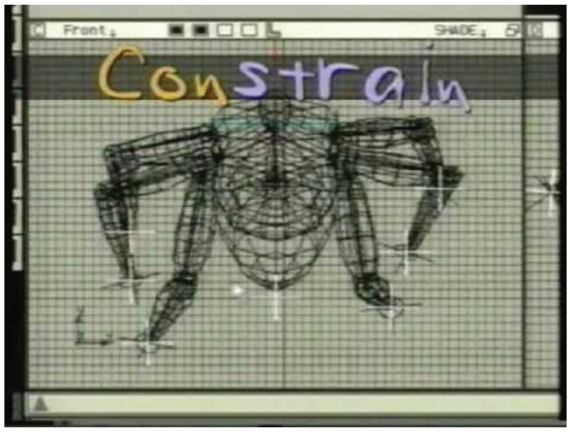
Softimage customers include some of the most prominent production studios, such as Industrial Light and Magic, Digital Domain, Sega, Nintendo, and Sony . They have used Softimage to create animation for hundreds of major feature films (*Jurassic Park, Titanic, The Matrix, Men in Black, Star Wars – the Phantom Menace, Gladiator, Harry Potter, AI: Artificial Intelligence, Pearl Harbor, Queen of the Damned*), games (Super Mario 64, Tekken, Virtual Fighter, Wave Race, NBA Live) and thousands of commercial, corporate and student projects.

On October 23, 2008, Autodesk signed an agreement with Avid Technology to acquire the brand and the 3D animation assets of Softimage for approximately $35 million, thereby ending Softimage Co. as a distinct entity. The video-related assets of Softimage, including Softimage|DS (Avid|DS) continued to be owned by Avid. In 2014, Autodesk announced that it would “retire” Softimage and provide a migration platform for their customers to either the 3ds Max or Maya products.

Michael Burns. The Long and Lonely Death of Softimage, Digital Arts, March 17, 2014.

In the Spring of 1997 through an endowment provided by Daniel Langlois, the *Daniel Langlois Foundation* was established. It is a private philanthropic organization whose scope of activity is international. The purpose of the Foundation is to further artistic and scientific knowledge by fostering the meeting of art and science in the field of technologies. "The Foundation's mission is to promote contemporary artistic practices that use digital technologies to express aesthetic and critical forms of discourse, to encourage interdisciplinary or multidisciplinary research projects and, in general, to support the development of projects calling for cooperation between people from a variety of fields, such as artists, scientists, and engineers or technologists." explained the Foundation's Director of Programs, Jean Gagnon.

Movie 8.8 Softimage



Softimage Animation Reel (1995)
https://www.youtube.com/watch?v=LrNQQvAKO2o
This is Part 1 of 2. The second part can be viewed at
http://www.youtube.com/watch?v=xHeKXv4BY0M

8.7 Autodesk/Kinetix/Discreet



Autodesk Logo

Autodesk Inc. was founded in 1982 with a focus on design software for the PC. They went public in 1985. For a first-person account of the history, read **John Walker's** online history of Autodesk at *http://www.fourmilab.ch/autofile/* told through the letters and memos from and to the inner circle of the company.



John Walker

Autodesk in 1986 began efforts to develop an animation package. Key developers were Jamie Clay and Autodesk founder John Walker. Autodesk's first animation package was AutoFlix (for use with AutoCAD and AutoShade), and AutoFlix 2.0 which included the Animation Tool Kit for AutoCAD.

In early 1988, Gary Yost left Antic, developers of software for the Atari, to pursue a contract development deal with Eric Lyons and David Kalish at Autodesk and to begin work on Autodesk 3D Studio (code-named THUD after its principal developer Tom Hudson), and Autodesk Animator. Gary brought Jack Powell along, too, and the Yost Group, Inc. was born. (The Yost Group was eventually bought by Autodesk.)

At the 1989 SIGGRAPH in Boston, Autodesk unveiled a new PC based animation package called Autodesk Animator. As a full featured 2D animation and painting package, Animator was Autodesk's first step into the multimedia tools realm. The software-only animation playback capabilities achieved very impressive speeds and became a standard for playing animation on PCs.

This early PC based animation software was used to visualize how nano machines might look. This animation was used in the BBC documentary "Little by Little" and was the first time an Autodesk animation product had been used for broadcast television.

Shortly before the release of the next generation of 3d Studio in 1996, the product MAX, the Multimedia Division of Autodesk was renamed to Kinetix, A Division of Autodesk. MAX shipped as Kinetix 3D Studio MAX. Since

its release in 1997, 3D Studio VIZ continues to gain more acceptance within the architectural community for design and visualization. As a result it has shifted more specialized architectural users from MAX to VIZ. 3D Studio VIZ enables professionals in the architectural, land design and mechanical design sectors to design in 3D Studio VIZ and then transfer the images directly into a CAD environment.

Discrete Logo

Discreet, a division of Autodesk, was established in 1999 after Autodesk acquired Discreet Logic Inc. for US$520M and merged its operations with Kinetix®. Autodesk is the world's leading design and digital content creation resource. The company provides software and Internet portal services to help customers drive business through the power of design. One of the largest software companies in the world, Autodesk helps more than 4 million customers in over 150 countries turn designs into reality.

From an investment banker's research analysis:

"Since its launch, 3D Studio Max has had a phenomenal impact on the 3D animation market. Originally priced much lower than some of its counterparts who's products ranged anywhere from $10,000 to $45,000, 3D Studio Max was quickly viewed as the attainable solution for professionals that had some price/performance issues. It continues to maintain strong price/performance value for users and the product's expectancy remains high. One of the key success factors of 3D Studio Max has been the product's ability to address the needs of a wide range of 3D animation professionals. Of all the animation packages 3D Studio Max runs across more vertical markets than any other package. Its largest user base continues to be within the game development sector. Aside from game development, it is used in film and broadcast, corporate design, industrial design and visualization, educational, forensic, and now Internet design."

One of the keys to this broad base of users is it's open architecture and support of third party vendors. This has enabled the product to build up over 100 plug-in products for more specialized functionality. Third party developers can develop standalone software modules (plugins) which can interface with the 3D Studio product. One of the more prominent plugins is Character Studio, developed by *Susan Amkraut and Michael Girard* of Unreal Pictures. Girard and Amkraut were the creators of the famous animation *Eurhythmy* while they were students at Ohio State, and developed the cult legend "*Dancing Baby*" as a test of their software. In 2004, Autodesk division *Discreet acquired Unreal Pictures*.

In January of 2006 Autodesk acquired Alias for $197M in cash, bringing the StudioTools and Maya software products under the Autodesk banner.

Movie 8.9 Eurythmy

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/eurythmy-1.m4v

This video is an excerpt from the movie Eurythmy by Michael Girard and Susan Amkraut.

Movie 8.10 Baby Cha

https://osu.pb.unizin.org/graphicshistory/

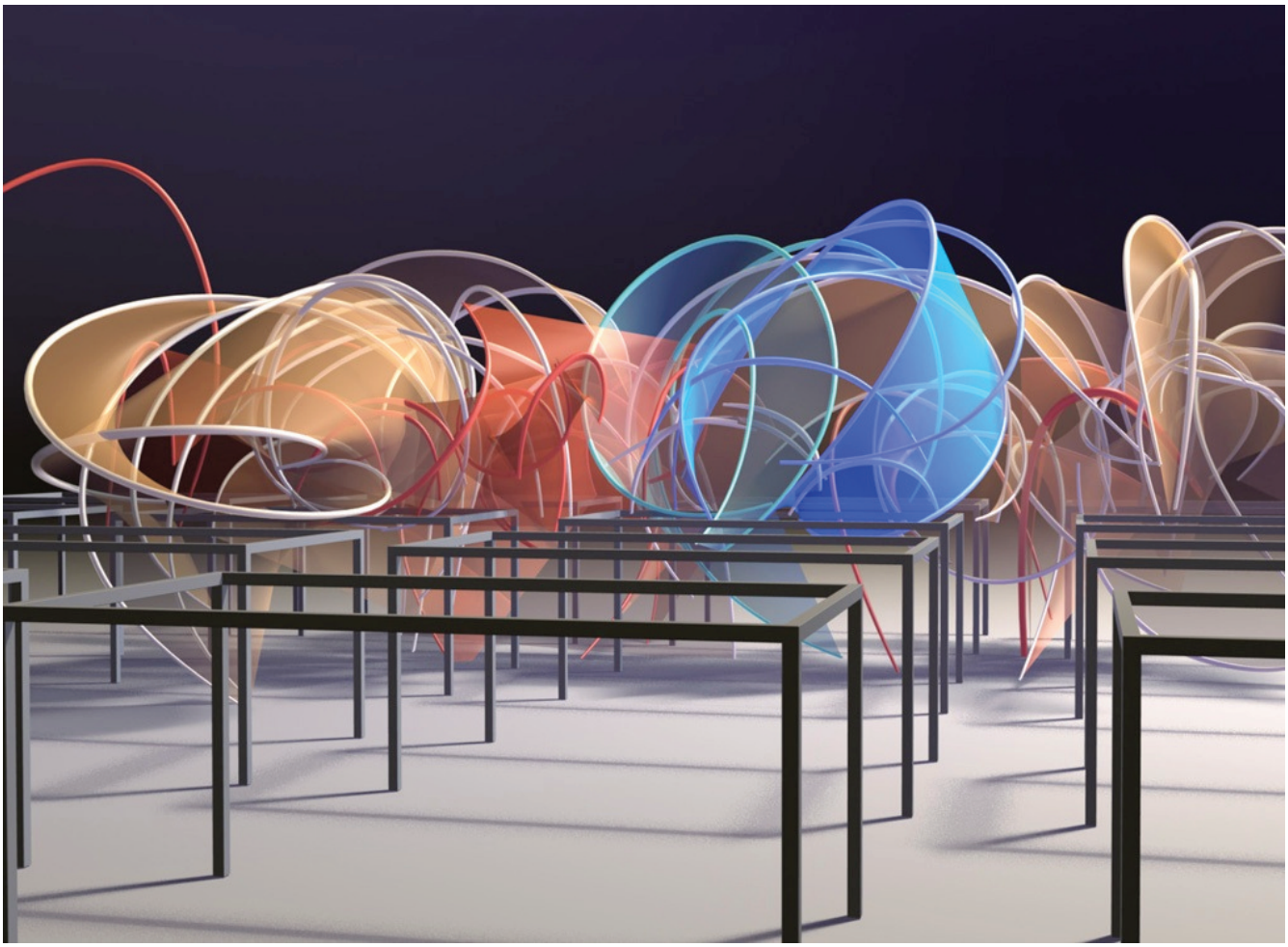
wp-content/uploads/sites/45/2017/04/baby1-1.m4v

Michael Girard of Unreal Pictures originally used the surreal Dancing Baby figure as a sample to show off his animation software. It evolved as a popular Internet "meme"

Chapter 9: Computer Artists

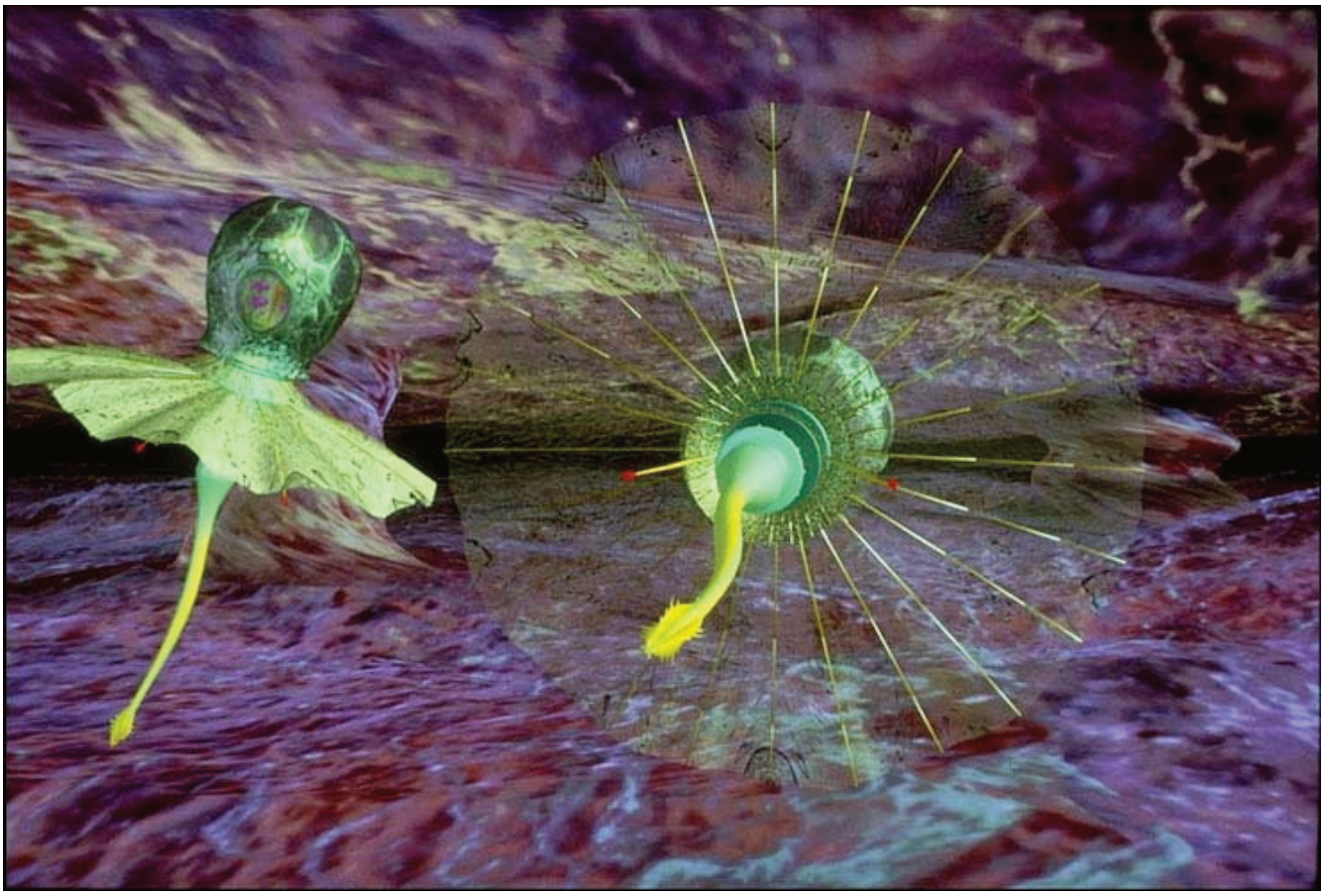
Computer Artists

As computer graphics software developed, many of the earliest users of this new technology were artists, or in some cases, scientists using the image making capabilities to create artwork.



Animation of dancer's traceforms in One Flat Thing, reproduced to map to 3D space.
Credit: Synchronous Objects Project, The Ohio State University and The Forsythe Company (2009)

9.1 Introduction



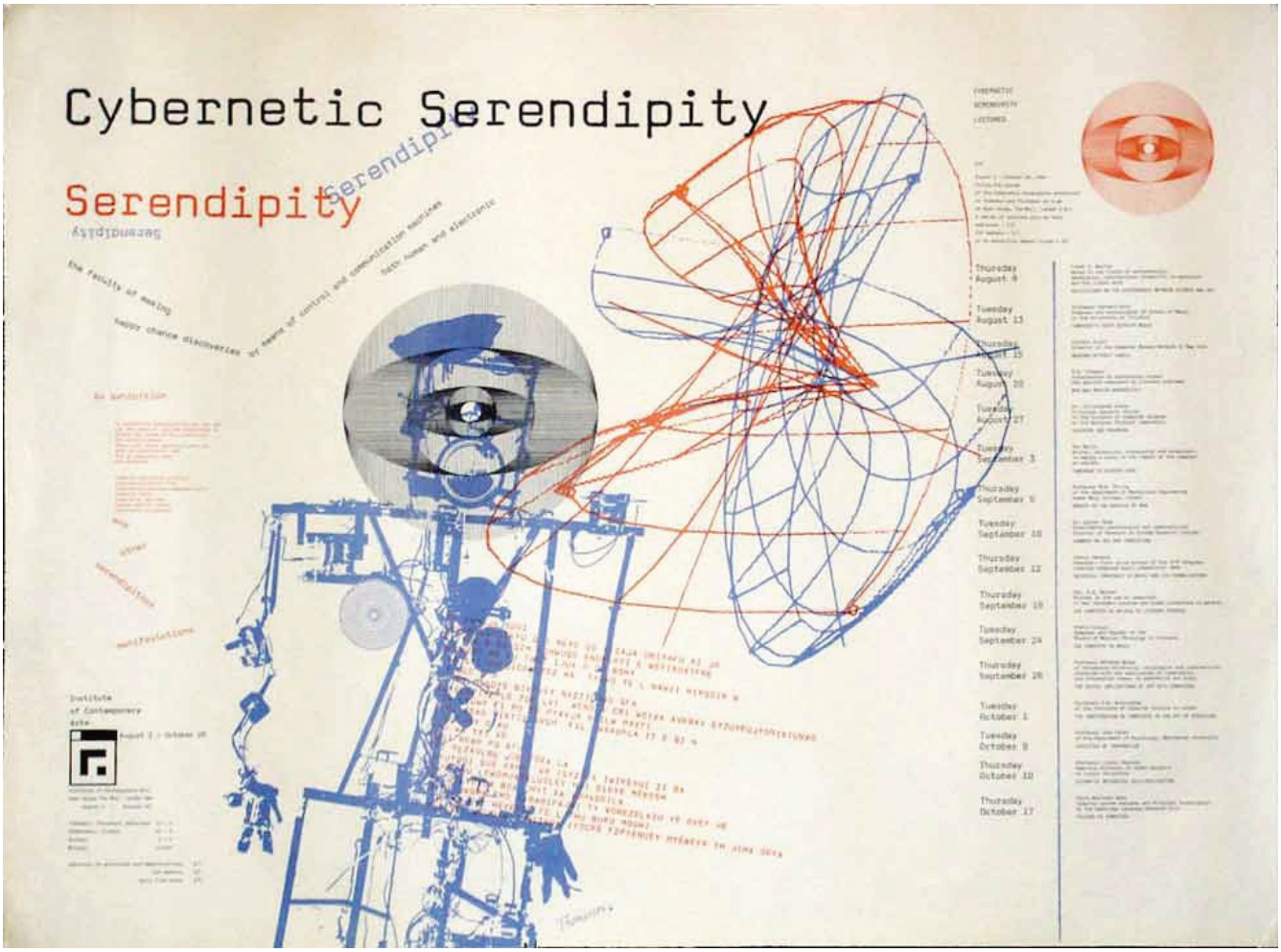
The mid-1960s saw many artists becoming interested in the creative activities at the confluence of art and technology. Previously, most individuals involved in the creation of computer art were in fact engineers and scientists. This was due to several factors: 1) access to mainframe computers, the only kind of computing resource available at the time, was available only to scientists at industrial and university scientific research labs; 2) there was no real interactive software, requiring the scientific programming expertise of the engineers or scientists; 3) the process of art-making on the computer was very algorithmic in nature, which was not necessarily the way traditional artists were used to thinking; and 4) the art community was hesitant to regard the new art form as a reputable or even acceptable art form.

In spite of this, and maybe in part because of this, collaborations between artists and scientists began, and in many cases flourished. It was not without difficulty, however. As Ken Knowlton portrayed the two mindsets:

> **Artists are** illogical, intuitive, and impulsive
> **Scientists are** constrained, logical, and precise

In many cases, the scientists themselves were portrayed as, or at least called themselves artists. In some cases, artists learned the complexities of interacting with the computer and became hybrid in their approach. The first two exhibitions of computer art (at the Wise Gallery in New York and in Stuttgart Germany, both in 1965), were organized by scientists. Most of the submissions, and nearly all of the selections were from scientists. Nevertheless, they were important events in the establishment of computer art as a recognized and eventually an accepted art form.

In 1966, Bell Labs engineer Billy Klüver and artist Robert Rauschenberg founded a formal entity to “develop an effective collaboration between the artist and the engineer.” This organization was very important in recognizing the important intersections between the artist and the computer. Called the *E.A.T.* (Experiments in Art and Technology) it provided an environment that encouraged important artistic creations, including collaborations between contributors such as Kluver, Andy Warhol, Rauschenberg, John Cage and Jasper Johns. Support was in part provided by Bell Labs.



Cybernetic Serendipity Poster (1968)

One of the most important early artistic exhibitions of computer art and digital installations was called *Cybernetic Serendipity*, which was held in 1968 at the Institute of Contemporary Arts in London. Organized by Jasia Reichart, it included most of the important contributors to the technology art world at the time, including Charles Csuri, Michael Noll, Nam June Paik, Frieder Nake, John Whitney, John Cage and others. Although it was not the first computer art exhibition, it is acknowledged as an important milestone in the recognition of this new medium in the art world.

Cybernetic Serendipity ran for two months and featured exhibits from 325 participants from around the world. They showed off the latest in computer graphics and some early computer-composed music. There were robots and drawing machines and the first computer sculpture.

The exhibition was the first of its kind in Britain and the curator Jasia Reichardt wrote that it showed how “man can use the computer and new technology to extend his creativity and inventiveness.” It later traveled to Washington, DC and San Francisco between 1969-70.

In several previous chapters, most notably Chapter 4, several pioneering computer artists (Whitney, Laposky, Noll, Csuri, Knowlton, vanderBeek, Foldes, Em, and others) were featured. This section highlights several more artists, representing artistic activities that have contributed to the broader discipline of computer graphics and

animation; it is not intended to be an exhaustive treatment of the computer art discipline; that is beyond the scope of this document. I refer you to several sources, including the online Digital Art Museum, Cynthia Goodman's book *Digital Visions* , and *The Computer in the Visual Arts* by *Anne Morgan Spalter* for more information in this regard.

Dietrich, Frank, "*Visual Intelligence: The First Decade of Computer Art (1965-1975)*", Leonardo, V19 #2, pp. 159-169, 1986

Franke, Herbert, *The New Visual Age: The Influence of Computer Graphics on Art and Society*, Leonardo, Vol. 18, No. 2, pp. 105-107, 1985.

Jones, Beverly, *Computer Imagery: Representation and Realitie*s, Leonardo, International Journal of Science and Art , Computer Art in Context: 1989 A Special Edition Juried by the Special Interest Group in Graphics (SIGGRAPH) Association of Computing Machinery (ACM)31- 38.

Macgregor, Brent, *Cybernetic serendipity revisited*, Proceedings of the fourth conference on Creativity & cognition, Loughborough, UK
pp, 11 – 13, 2002

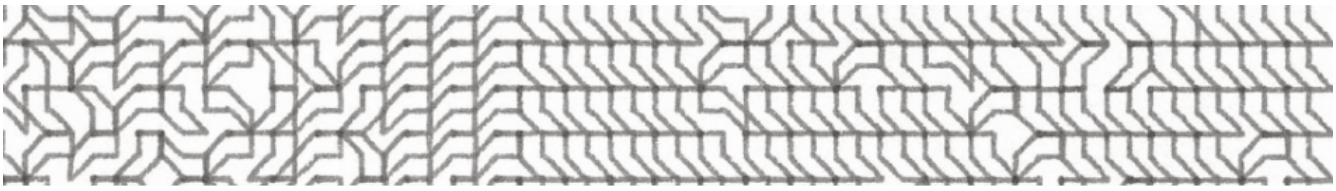
Digital Art Museum timeline
http://www.dam.org/timelines/artists

An essay specially written by Mike King for the Digital Art Museum, traces the relationship between the Pioneers of computer fine art and Modern art movements.
http://www.dam.org/essays/king-digital-art-museum-2002

Goodman, Cynthia, *Digital Visions: Computers and Art*, Abrams, 1987 (published in connection with the exhibition Computers and Art at the Everson Museum of Art in Syracuse, NY, 1987)

Spalter, Anne Morgan, *The Computer in the Visual Arts* (Addison Wesley) 1999

9.2 Vera Molnar



Vera Molnar was born in 1924 in Budapest, Hungary. After studying at the Budapest Academy, she received her diploma in 1947 in Art History and Aesthetics. Her artwork has always been focused on abstract and geometrical paintings. That same year, she received the Rome Scholarship and moved to Paris.

In 1960, Molnar co-founded the “Groupe de recherche d’art visuel” , or GRAV (GRAV was founded in July 1960 by Vera Molnar, François Morellet, Horacio Garcia Rossi, Julio Le Parc, Francisco Sobrino, Joël Stein, and Jean-Pierre Yvaral).This group was a proponent of stripping the content away from the visual image in their medium in order to focus on seeing and perceiving. They were instrumental in the **Op-art** and **Kinetic Art** movements of that decade. Molnar was also co-founder of the group “Art et Informatique” at the “Institut d’Esthetique et des Sciences de l’Art” in Paris in 1967.

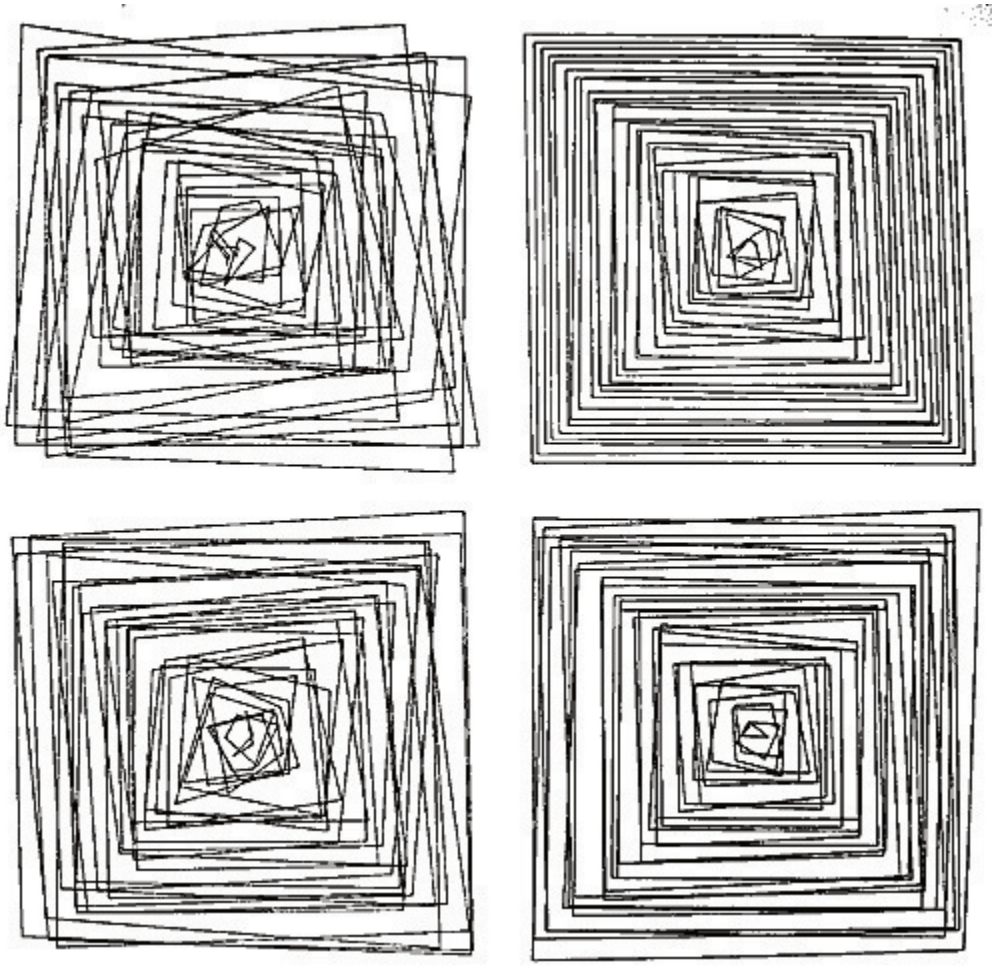
According to Molnar, in her eyes her work has a hypothetical character. In order to systematically process her research series, she invented a “technology”, which she called “Machine Imaginaire”. She sketched a program, and then, step by step, realized a simple, limited series, which was self-contained.

In 1968 she discovered the power of the computer to allow an artist to step away from “the social thing” in order to get at the real creative vision. She replaced the illusory computer, the invented machine, by a genuine computer. Her initial work involved transformations of geometric objects, such as a square, by rotating, deforming, erasing all or parts of them, or replacing portions with basic elements of other geometric shapes. She would often repeat the geometric primitives while fracturing or breaking them as she transformed them, ultimately outputting them to a plotter.

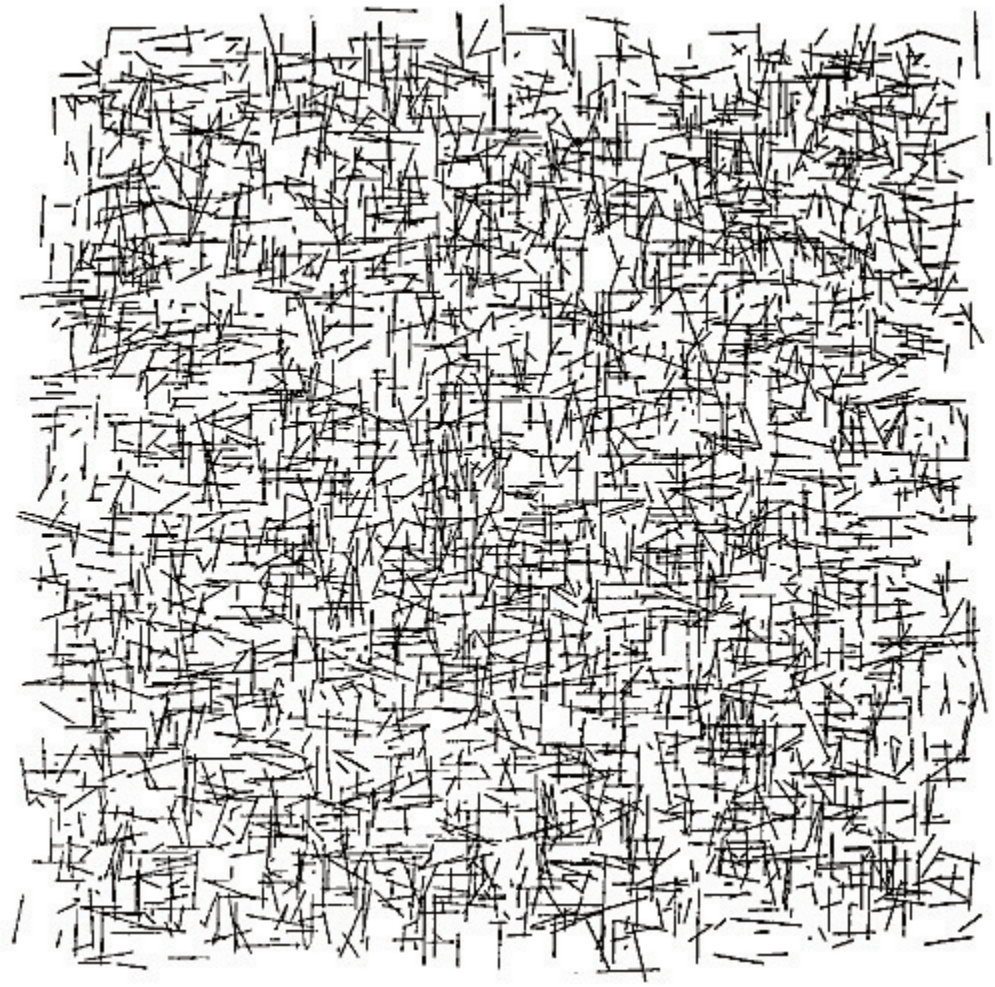
Molnar did work at the Centre Pompidou, ARTA (Atelier du Recherche des Techniques Avancees) and was a member of the CREIAV (Centre de Recherche Experimentale et Informatique des Arts Visuels). In 1985 she became a Professor at the University of Paris, Sorbonne.

> “Proceeding by small steps, the painter is in a position to delicately pinpoint the image of dreams. Without the aid of a computer, it would not possible to materialize quite so faithfully an image that previously existed only in the artist’s mind. This may sound paradoxical, but the machine, which is thought to be cold and inhuman, can help to realize what is most

subjective, unattainable, and profound in a human being."
From Frank Popper's Visualization, Cultural Mediation and Dual Creativity in Leonardo.

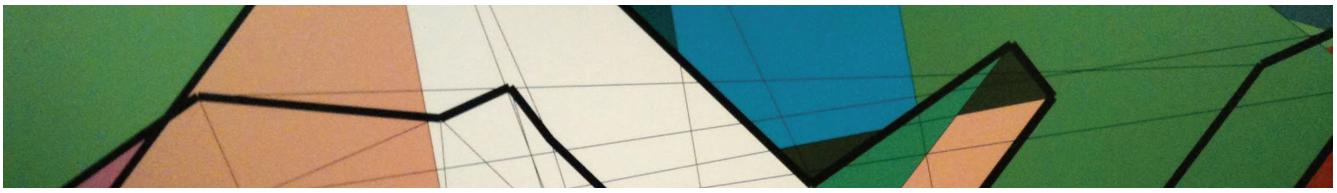


Du Cycle – Carres Non Concintriques, 1974

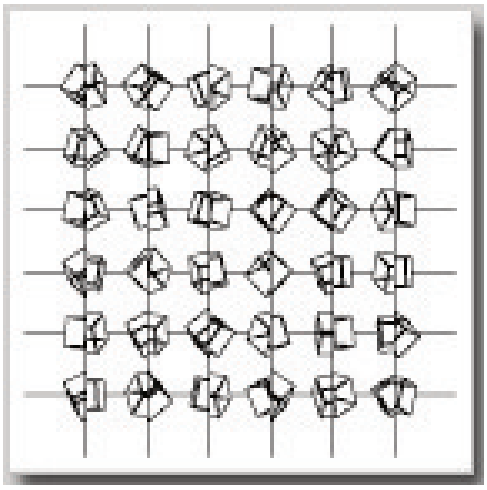


Mondrian Derange, 1974

9.3 Manfred Mohr



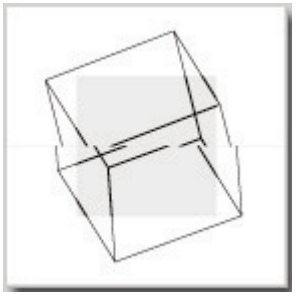
Manfred Mohr was born in 1938 in Pforzheim (Germany). He studied lithography at the Ecole des Beaux Arts, in Paris. He turned from traditional painting to the computer in 1969 to realize his artistic interest in **Constructivist** artforms. He focused his artistic vocabulary and aesthetic expression by working only in black and white, not reverting to a color palette until 1998, using a plotter as output from the computer.



Cubic Limit II

As quoted by Goodman in her book Digital Visions, Mohr says "The paradox of my generative work is that form-wise it is minimalist and content-wise it is maximalist." He has chosen the cube, and the seemingly uncountable variations of it as his primitive element. Mohr has the computer start with a cube and transform it through distortions and various rotations. According to Mohr, "Since 1973, in my research, I have been concentrating on fracturing the symmetry of a cube (including since 1978
n-dimensional hypercubes), using the structure of the cube as a "system" and "alphabet". The disturbance or disintegration of symmetry is the basic generator of new constructions and relationships."

Former Ohio State University Eminent Scholar in Design, Mihai Nadin said of Mohr, “In order to free his explorations from the burdens of psychological patterns, Manfred Mohr literally harnesses randomness and makes it operate on the entities selected for exploration. “

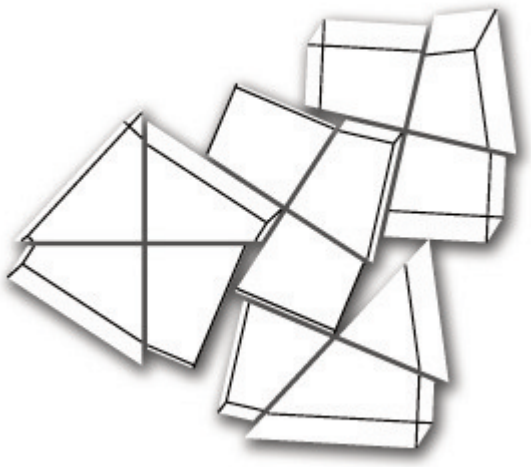


Cubic Limit II

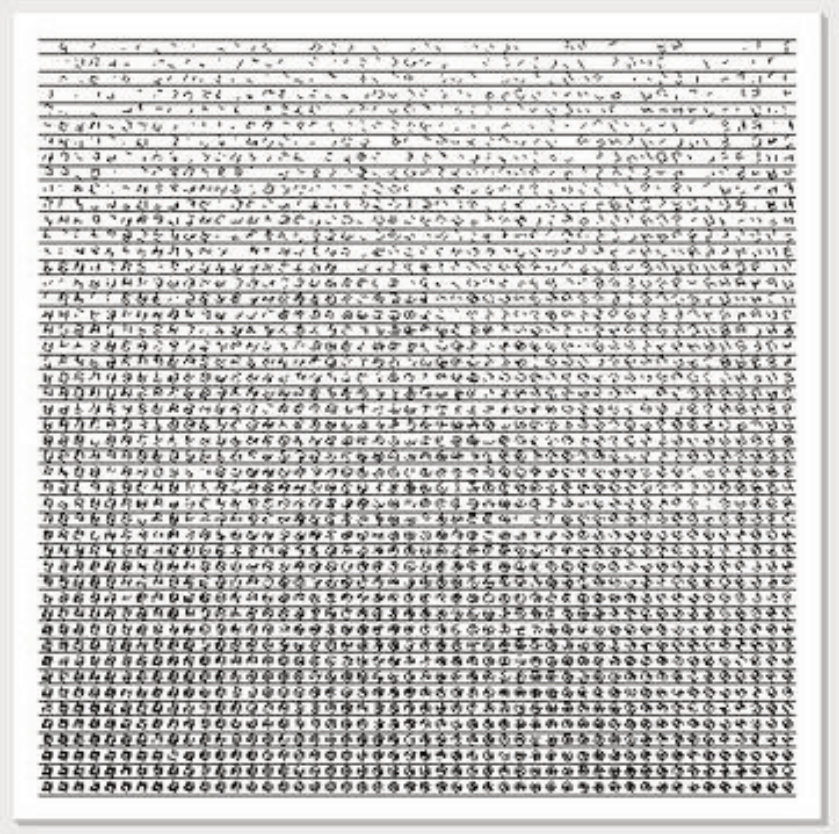
In 1971, Mohr was featured in a one-man show at the Musee d’Art Moderne de la Ville de Paris, which has been marked as the first museum sponsorship of a one-man exhibition of computer art. Mohr has also been honored by winning Ars Electronica in Linz.

> “The computer became a physical and intellectual extension in the process of creating my art. I write computer algorithms i.e. rules that calculate and then generate the work which could not be realized in any other way. It is not necessarily the system or the logic I want to present in my work, but the visual invention which results from it. My artistic goal is reached, when a finished work can visually dissociate itself from its logical content and convincingly stand as an independent abstract entity.”

Manfred Mohr Retrospective on the Rave WebMuseum of Cyberart



Divisibility II



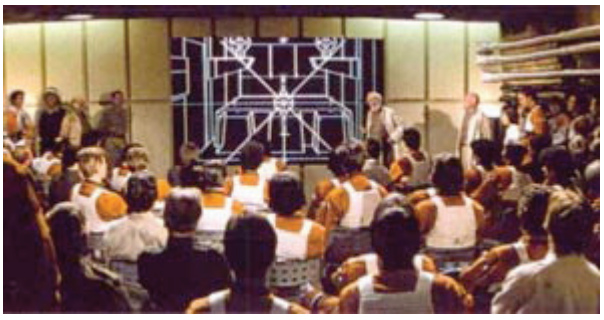
Cubic Limit I

9.4 Larry Cuba



Larry Cuba is widely recognized as a pioneer in the use of computers in animation art, and was one of the "hybrid" artist/technologists" that were referred to in Chapter 3. According to Gene Youngblood, "Larry Cuba works in the tradition known variously as abstract, absolute or concrete animation. His works are characterized by cascading designs, startling shifts of perspective and precise, mathematical structure."

In his own words, Cuba describes his work as: "…consist[ing] of experimenting with algebraic structures to generate visual material that is unpredictable in its form. By that I mean that it was not designed, imagined or otherwise pre-visualized. The results are only known after the program is run, the computer executes the computations and produces the animation."



Briefing from the movie Star Wars; graphics done by Cuba on DeFanti's GRASS system at UICC

To accomplish his work, much like was done by other early computer artists (such as John Whitney, Sr., Stan Vanderbeek, Chuck Csuri, Lillian Schwartz), Cuba started in the CG filmmaking efforts by gaining access to large mainframes, most notably those at NASA's Jet Propulsion Lab. This is the same facility where Jim Blinn did his seminal work. It was there that he completed his first piece in 1974, *First Fig*. According to Cuba, he showed this film to George Lucas as a means of convincing Lucas to let him work on the creation of graphics for the *Star Wars* movie.

In 1975, John Whitney, Sr. was in the process of making his film *Arabesque*, and invited Cuba to provide programming assistance. He did, and he learned much from the foot of the master during this collaboration about the relationship between the visual image and music, so much so that Youngblood called him "the Bach of abstract animation."

Later that year he was resident at the University of Illinois Chicago *Circle Graphics Habitat*, working with Tom DeFanti on the GRASS system that he developed as a graduate student at Ohio State and was pushing further

into the computer art application world. It was on this system that Cuba produced the graphics for the training sequence for the attack on the Death Star in Star Wars. He commented in an interview that he pushed the system to the limit, so much so that the computer kept crashing. It was only by working in the frigid temperatures of the room with the AC turned way up that he was able to keep the computer running in order to complete the filming.



Frame from Two Space

Cuba completed two more computer-animated films: *3/78 (Objects and Transformations)*, and *Two Space* using similar approaches to designing and producing and filming the graphics.

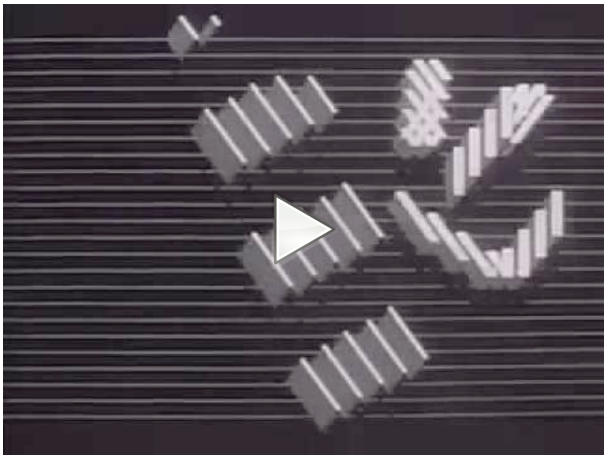
DeFanti extended the GRASS system to be used on a personal computer which resulted in the development of the ZGRASS environment (Chapter 5, Section 4). Cuba purchased a ZGRASS system, for his personal use, and completed his film *Calculated Movements* using this new approach, and used a LyonLamb system to record it. According to Cuba, the filmmaking effort for this production was different. "The most obvious difference comes directly from the hardware. The other films were done on vector systems, so I was using dots. Going to the Zgrass machine meant not only going down from a mainframe to a mini to a micro but also going from vector to raster graphics. So this is my new palette, so to speak. New in two ways: I could draw solid areas so that my form became delineated areas instead of just dots, and I had four colors: white, black, light grey and dark gray."

Cuba studied at Washington University and at *The California Institute of the Arts*, where he received his MFA. He has won both NEA and AFI Independent Filmmakers grants and his works have screened in many exhibitions, including Trickfilm/Chicago (1980) and the Best of Hiroshima '85. Cuba was also an artist-in-residence at the Institute for Visual Media of the ZKM in Karlsruhe, Germany.

His works have been shown at film festivals throughout the world and have won numerous awards. Cuba has presented his work at SIGGRAPH, ISEA, Ars Electronica, and other, and his films have been included in screenings at top-end museums throughout the world.

Cuba received grants for his work from the American Film Institute and The National Endowment for the Arts and was awarded a residency at the Center for Art and Media Technology Karlsruhe (ZKM). He has served on the juries for the SIGGRAPH Electronic Theater, the Montpellier Festival of Abstract Film, The Ann Arbor Film Festival and Ars Electronica.

Movie 9.1 Larry Cuba



Short sequence from Calculated Movements
https://www.youtube.com/watch?v=HcvN1dt0yJo

Calculated Movements, An Interview with Larry Cuba, Video and the Arts Magazine, Winter 1986, Gene Youngblood.

Star Wars: Episode IV – A New Hope: Making of the Computer Graphics for Star Wars, *http://www.movieweb.com/movie/star-wars-episode-iv-a-new-hope/making-of-the-computer-graphics-for-star-wars*

9.5 Lillian Schwartz





Lillian Schwartz

The following text is taken from the artist's website at ***http://www.lillian.com***

Lillian Schwartz is best known for her pioneering work in the use of computers for what has since become known as **computer-generated art** and computer-aided art analysis, including graphics, film, video, animation, special effects, Virtual Reality and Multimedia. Her work was recognized for its aesthetic success and was the first in this medium to be acquired by The Museum of Modern Art. Her contributions in starting a new field of endeavor in the arts, art analysis, and the field of virtual reality have been recently awarded Computer-World Smithsonian Awards.

Schwartz began her computer art career as an offshoot of her merger of art and technology, which culminated in the selection of her kinetic sculpture, Proxima Centauri, by The Museum of Modern Art for its epoch-making 1968 Machine Exhibition. She then expanded her work into the computer area, becoming a consultant at the AT&T Bell Laboratories, IBM's Thomas J. Watson Research Laboratory and at Lucent Technologies Bell Labs Innovations. On her own, and with leading scientists, engineers, physicists, and psychologists, she developed effective techniques for the use of the computer in film and animation.

Besides helping to establish computer art as a viable field of endeavor, Schwartz additionally contributed to scientific research areas such as visual and color perception, and sound. Her own personal efforts have led to the use of the computer in the philosophy of art, whereby data bases containing information as to palettes and structures of paintings, sculptures and graphics by artists such as Picasso and Matisse are used by Schwartz to analyze the choices of those artists and to investigate the creative process itself.

Her contributions to electronic art analysis, and restoration, have been recognized, specifically in Italian Renaissance painting and frescoe. Her work with colleagues to construct 3-dimensional models of the Refectory

at Santa Maria Grazie to study the perspective construction of Leonardo's Last Supper and, more recently, a finite element model of the Leaning Tower of Pisa to aid in the preservation of the tower in understanding its structure, have proved invaluable to Art Historians and Restorers.

Schwartz's education began immediately after World War II when she studied Chinese brushwork with Tshiro in Japan. Over the following years she studied the fine arts with professionals such as Giannini, Kearns, and Joe Jones. She is self-taught with regard to film and computer interfacing, and programming.

Schwartz has always had close ties to the academic community, having been a visiting member of the Computer Science Department at the University of Maryland; an adjunct professor at the Kean College, Fine Arts Department; an adjunct professor at The Rutger's University Visual Arts Department; an adjunct professor at the Psychology Department, School of Arts and Sciences, New York University; and is currently a member of the International Guidance Panel, under the co-sponsorship for The Society for Excellence Through Education, Israel, Teachers College, Columbia University and S.A.G.E., and a Member of the Graduate Faculty of The School of Visual Arts, NYC. She has also been an Artist in Residence at Channel 13, WNET.



Lillian Scwartz

Schwartz's work has been much in demand internationally both by museums and festivals. For example, her films have been shown and won awards at the Venice Biennale, Zagreb, Cannes, The National Academy of Television Arts and Sciences, and nominated and received Emmy nominations and award. Her work has been exhibited at and is owned by museums such as The Museum of Modern Art, The Metropolitan Museum of Art, The Whitney Museum of American Art, The Moderna Museet (Stockholm), Centre Beauborg (Paris), Stedlijk Museum of Art (Amsterdam), and the Grand Palais Museum (Paris).

Representing the United States, Schwartz has been a guest lecturer in over two dozen countries, ranging from the Royal College of Art in London to the US/China Cultural Relations speaker in the People's Republic of China. Schwartz has also had numerous other fellowships, and honors conferred upon her, including a Doctor of Humane Letters Honoris Causa from Kean College, New Jersey, and grants from the National Endowment For The Arts and The Corporation For Public Broadcasting. Most recently she has received Computerworld Smithsonian Awards in three categories: For the Application of the Computer as a Medium in the Arts, including Graphics, Film/Video, and Special Effects; pioneering work in the field of Virtual Reality; and for her contributions in special editing techniques in Media and Arts & Entertainment.



The Hidden Mona Lisa © Lillian Schwartz

She has been the subject of numerous articles, books, and television news and documentary programs. She is a Fellow in The World Academy of Art & Science. She has been appointed as a committee member of the National Research Council Committee on Information Technology and Creativity under the Computer Science and Telecommunications Board of The National Academies from May, 2000 to December, 2001. Schwartz is the author (together with Laurens R. Schwartz) of The Computer Artist's Handbook, W.W. Norton & Company.

Additional information can be viewed in Chapter 4, Section 2 – Bell Laboratories. Three early films by Lillian Schwartz (Pixellation, The Artist and the Computer, and UFOs), followed by a 2011 discussion between the artist and Dan Streible, the programmer of "Sonic Truth", the 2011 Flaherty Seminar, can be seen at *https://vimeo.com/31521570*.

9.6 David Em



Artist **David Em** was hired at JPL as an artist-in-residence, and adapted scientist Jim Blinn's visualization software to realize his own artistic ideas. Em admitted, though, that the JPL deep space environment influenced the quality and look of his artwork. From the Digital Art Museum entry on David Em:



Artist David Em at the display at JPL

David Em started as a painter but in 1974 began to experiment with electronic manipulations of TV images. This led to his involvement with the Xerox Research PARC in Palo Alto and to collaboration with computer graphics pioneers Alvy Ray Smith and Dick Shoup, inventor of the frame buffer. In 1976 Em had access to equipment at Triple-I, set up by Gary Demos and John Whitney Sr., but it was the introduction to the Jet Propulsion Laboratory (JPL) and the research work of pioneer James Blinn that led to Em's mature computer art style. The works produced at JPL led to the first ever artist's monograph published on digital art.[1]

Author Ray Bradbury made the following statement about David Em and his work, titled EM SQUARED, taken from the introduction page on Em's website.

We live in confusing times.

1. (The Art of David Em , published by Harry N. Abrams) More work from David Em can be seen at a siggraph profile website, http://www.siggraph.org/artdesign/profile/David_Em/

Books do not look like books. They sometimes resemble computer chips. This makes for a slight misalignment among some readers who refuse to pick up a computer chip to try to turn the pages

In the field of art a semipanic spreads. Artists, like many another in other fields, fear that the machine is here to mash their toes, chop their fingers, or put out their eyes.

The computer lurks with intention to loom. Men run down the middle of the streets crying, "The dam has broke!" forgetting they live in a town with no water and no dam.

Have you or have you not heard it said that the day is fast coming when the artists will be replaced by a robot. We will all retire from the field and leave the computer as mindless Michelangelo inside the church painting the far wall and the upper ceiling. When Godreaches down his Great Hand it will not touch Adam, it will touch Apple or Commodore or the Xerox Mark 10.

It's enough to make a chap turn in his oils and burn his canvases.

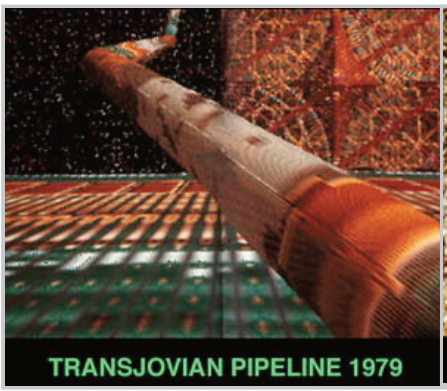
And yet. And yet…

Behold the work of David Em No computer, no robot, he. A man of flesh and wildly imaginative blood. But what's that he holds in his hand? Is it a brush, a tube of color, a jar of ink?It is not. It is, God help us all, the dread machine, the awful electric device that will fry and bury all art and artists. Yet, further behold. David Em is neither fried nor buried. HE is much alive, alive, O. And the landscapes of his imagination juice out his fingertips, through his pet Ben Franklin lightning bolt device, and flash as images not unlike those of childhood when someone struck your brow with a horseshoe or baseball bat. From these painful kaleidoscopic explosions Mr. Em has culled forth some bright new shapes and forms, told them to pull up their socks and behave, and delivered forth into our hands and eyes, a New Art Form. He has not, of course, done this alone. But he is preeminent in a field that is as swiftly flowing and changing as a storm stabbing its way across country walking on stilts of electric fire.

Ready or not, here he comes.

Watch his computerized, electric dust.

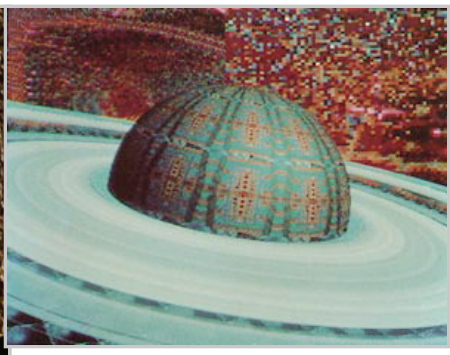
Gallery 9.1 David Em Artwork



Transjovian Pipeline



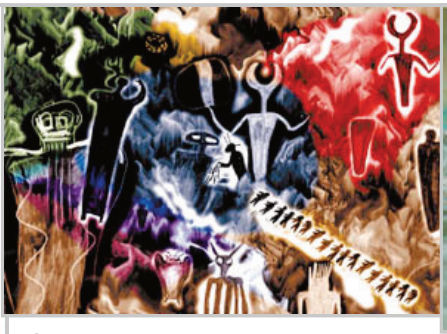
Nora



Dr. Jim, Number 1



Persepol

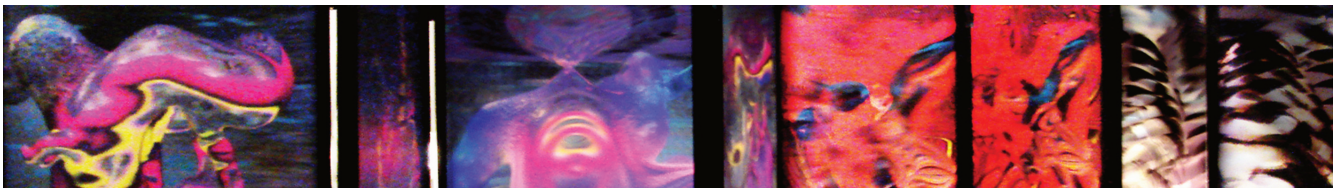


Utah Spirits



Far Away

9.7 Yoichiro Kawaguchi





Yoichiro Kawaguchi

One of the foremost international computer artists is **Yoichiro Kawaguchi** of Japan. Yoichiro Kawaguchi was born on Tanegashima Island in 1952. He received his Master of Fine Arts from Tokyo University of Education in 1978. Currently he is Associate Professor of Computer Graphics Art at Art & Science Lab, Department of Art, Nippon Electronics College, Tokyo.

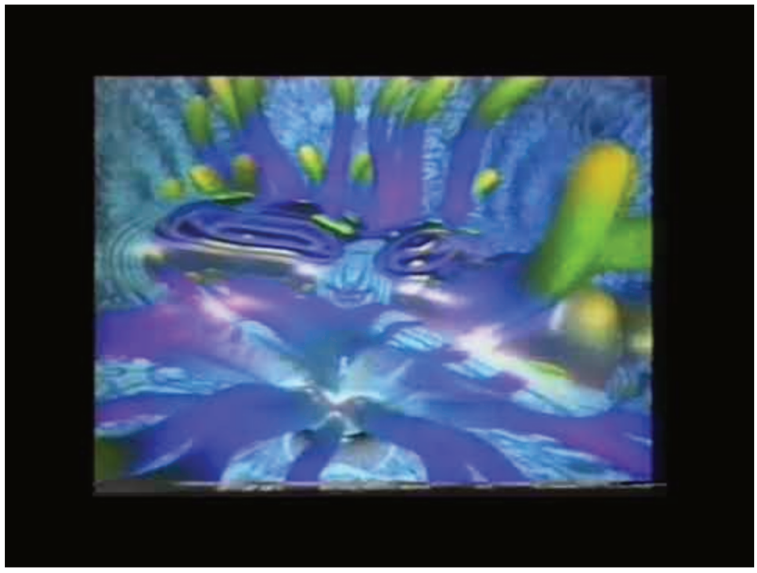
His early work was a collaboration with computer science researchers, who developed the LINKS computer, on which a lot of his work was produced. He used a technology called "**metaballs**" to get the soft, fluid, artistic forms of his organic shapes. Many of his algorithmic approaches to his art were taken from the growth patterns exhibited in seashells and spiraling plants.

Kawaguchi has exhibited at Biennale di Venezia 1986, Japan Pavilion EXPO 86, Vancouver, Ars Electronica, Linz 1986, AUSGRAPH '89, Sydney, and SIGGRAPH 90, Dallas. He has won numerous awards, e.g. "Eurographics '84"; Grand Prix PARIGRAPH '87; First Prize "Imagina '91".

Yoichiro Kawaguchi was awarded a Distinction by the Prix Ars Electronica jury for his entry Eggy in the category Computer Animation.

Kawaguchi had a long term collaborative relationship with Toyo Links, who developed hardware (LINKS-1) and software (TRACY) for raytracing meta-ellipsoids. Toyo Links also had a relationship with Hitoshi Nishamura and Prof. Omura at Osaka University. Toyo Links became Links Corp in 1988, and then started Imagica. They made a famous movie with creature motion, called BioSensor.

Movie 9.2 Interview with Yoichiro Kawaguchi



An episode from the UK Channel 4 series "283 Useful Ideas From Japan" first shown in 1990. The interview is in Part 2, which can be seen at
https://www.youtube.com/watch?v=6qKjd0QXQO4

Part 1 can be seen at
http://www.youtube.com/watch?v=nJH0fLTR7YU

Gallery 9.2 Yoichiro Kawaguchi Artwork



Frame from Eggy (1990)

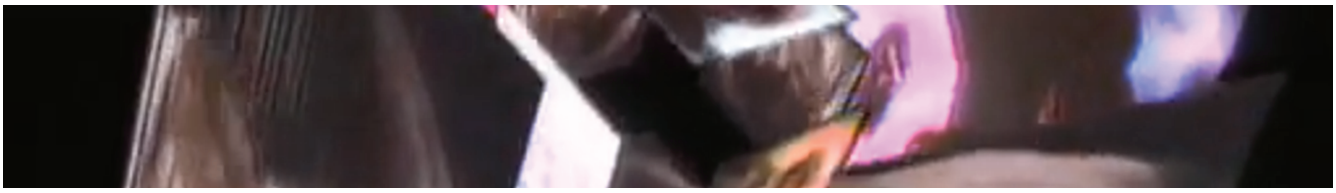


Kawaguchi artwork (1997)



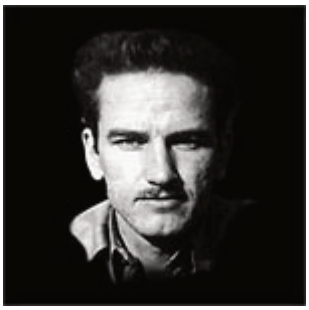
Kawaguchi artwork (1996)

9.8 Ed Emshwiller



The following is from a tribute to **Ed Emshwiller** from the CalArts web site:

> "Ed Emshwiller, the highly regarded video artist and dean of the School of Film/Video at the California Institute of the Arts, passed away July 27, 1990 from cancer at the age of 65.



Ed Emshwiller

Emshwiller was an influential figure in the experimental film movement that helped expand the horizons of American filmmaking in the 1960's and his work was frequently shown in museums and festivals.He studied art at the University of Michigan, the Ecole Nationale Superieure des Beaux-Arts in Paris and the Art Students' League. He was an **abstract expressionist** painter and award-winning science-fiction illustrator before turning his attention to film and video. Many of his experimental films, including Relativity, Totem, Three Dancers and Thanatopsis have received awards and screenings at film festivals in New York, London, Berlin, Edinburgh, Cannes and a number of other cities. He produced or collaborated on a number of multimedia productions at Lincoln Center, Museum of Modern Art, Guggenheim Museum, The Los Angeles Film Festival, among others. In early 1979, he produced the ground-breaking three-minute 3-D computer work entitled *Sunstone*, made at the New York Institute of Technology with the help of Alvy Ray Smith as software programmer.

> The same year, Emshwiller became dean of CalArts' film/video school. In addition to his duties as dean, he served as provost from 1981 through 1986. Robert J. Fitzpatrick, who was president of CalArts at the time of Emshwiller's appointments, said then, "Ed has demonstrated extraordinary gifts as an artist throughout his career… To his own surprise and our great benefit, he has shown a special talent for administration and leadership as dean of the School of Film/Video. He is the only person I know who could successfully combine triple careers of artist, dean and provost."
>
> Emshwiller was always looking for ways to push film and video's boundaries. This year, in fact, he was

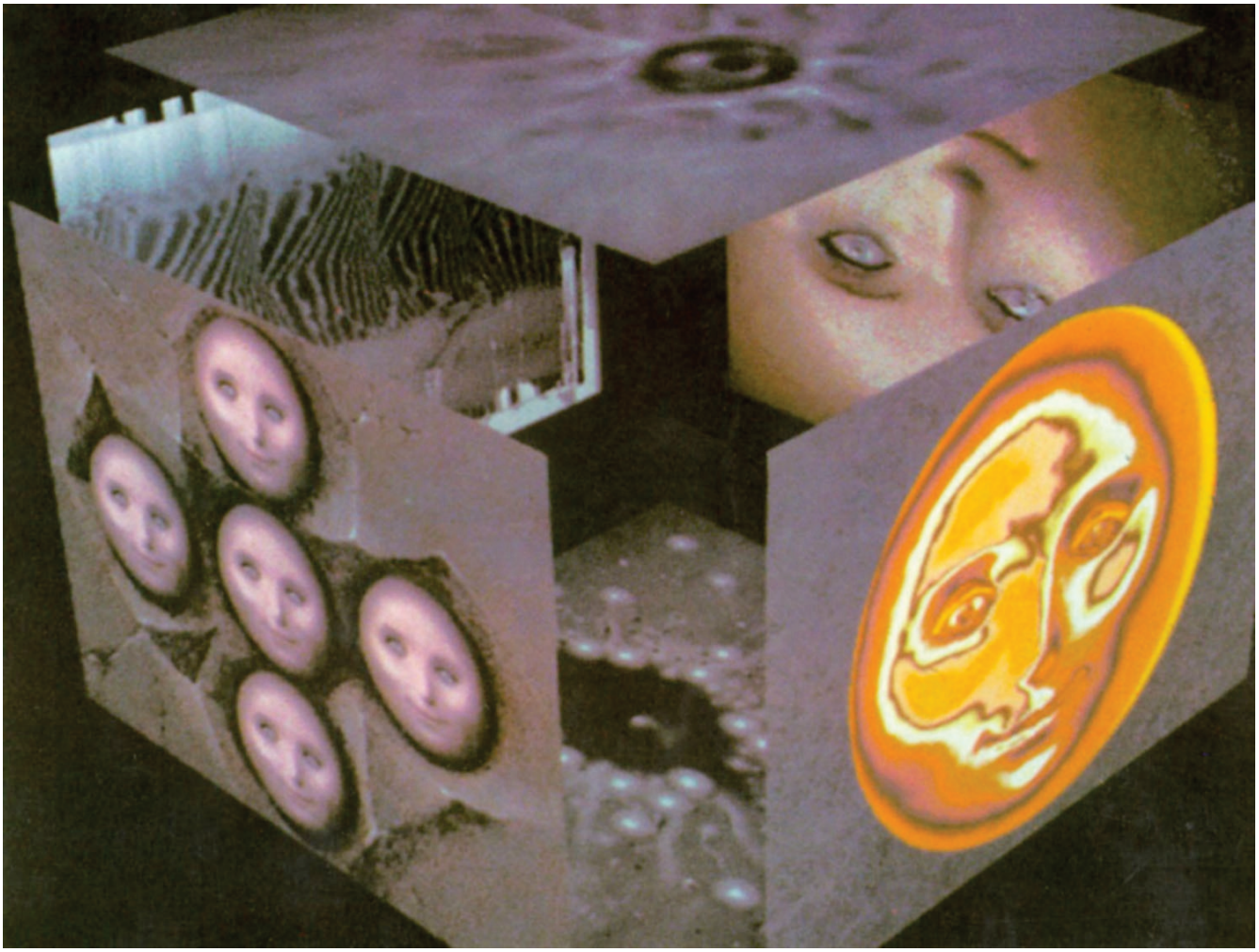
working with composer Morton Subotnick in, as Emshwiller described it, “interactive and three-dimensional performance with sound/image generation and various controlling devices.”

With Subotnick, Emshwiller created *Hungers*, an electronic video opera, for the 1987 Los Angeles Arts Festival. *Hungers* used live performance and interactive devices that changed the sound of the music according to the environment. No two performances were ever the same. In a similar fashion, their new work was going to play with video so that the images would change from performance to performance.

To Emshwiller, the innovative technique allowing for change was a way to ‘get film out of its can’. “The chaos theory, a slight deviation from a plan, will take you into a whole new realm of possibilities, and that’s one of the things, I think, exciting, not only philosophically, but also in terms of practice for devising performance.”

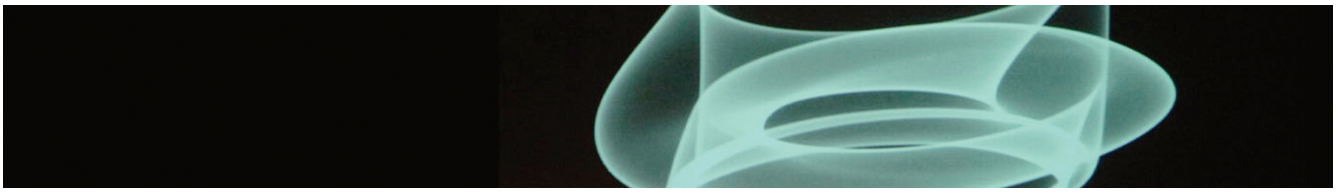
He received grants from the NEA, the Rockefeller, Ford and Guggenheim Foundations and the Corporation for Public Broadcasting. Emshwiller was a great influence in experimental film and video not only as an artist but also as an administrator. He was a member of the board of trustees of the American Film Institute, board of directors of the Filmmakers Cooperative, board of directors of the Association of Independent Video and Filmmakers, board of directors of the Independent Television Service, media panels of the NEA and the New York State Council for the Arts.

According to Ed’s wishes, his heirs donated to CalArts all his film equipment – valued at around $100,000 – and his complete archives. The latter, which occupies nearly two hundred feet of shelf space in CalArts’ special archival room, includes all his original films, outtakes, slides and notes on past and planned projects.”



Frame from Sunstone- Movie can be seen in Chapter 5 – Section 1

9.9 Other Artists



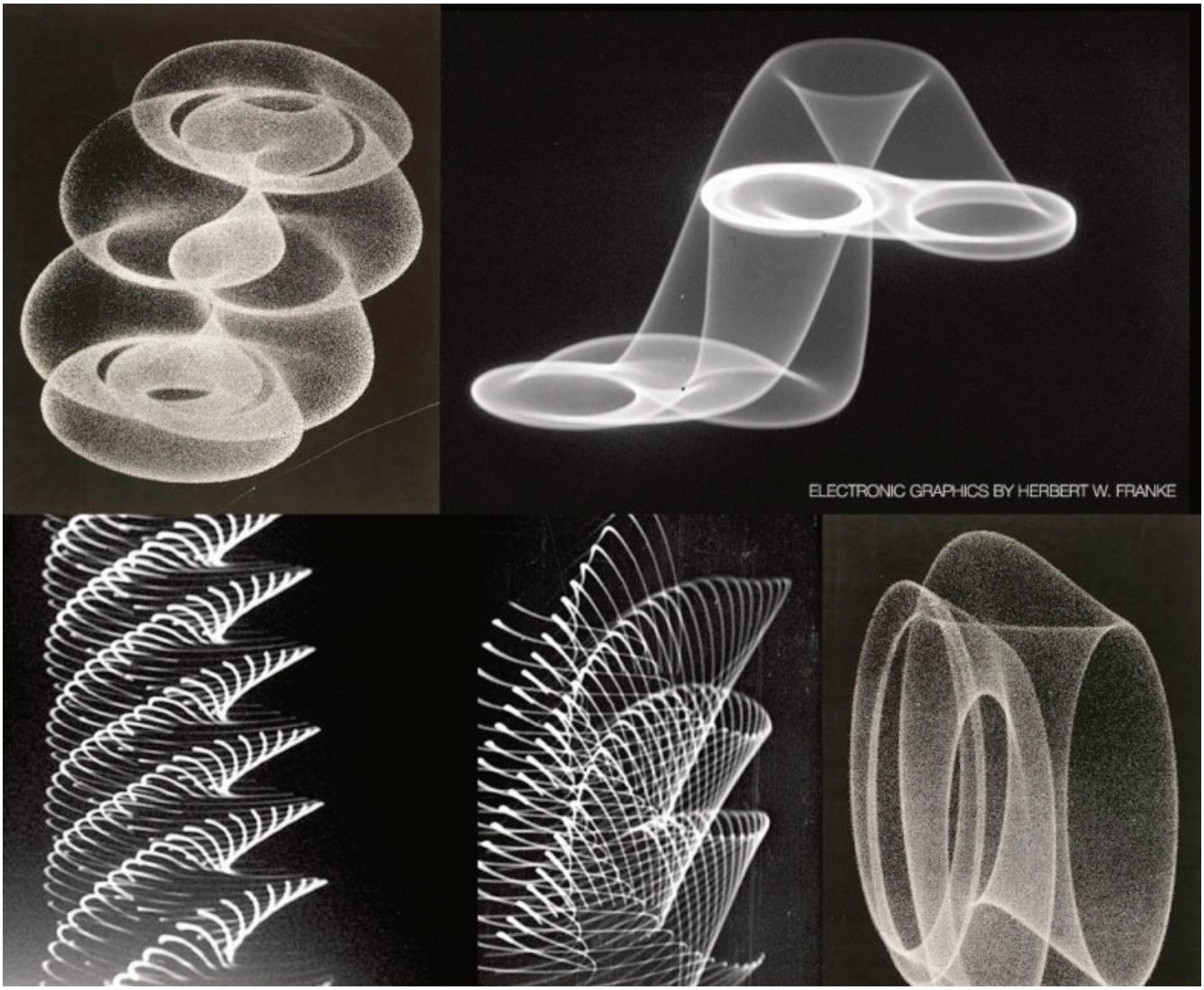
Several other early artists deserve mention at this point. Herbert Franke, Frieder Nake and George Nees from Germany, and Harold Cohen, Duane Palyka, Joan Truckenbrod, Darcy Gerbarg, and Colette and Charles Bangert from the United States each has contributed immensely to the evolution of computer art.

Also, video artists Nam June Paik, Bill Etra, Frank Dietrich, Jane Veeder, Vibeke Sorensen and Copper Giloth advanced that important component of the digital art movement.

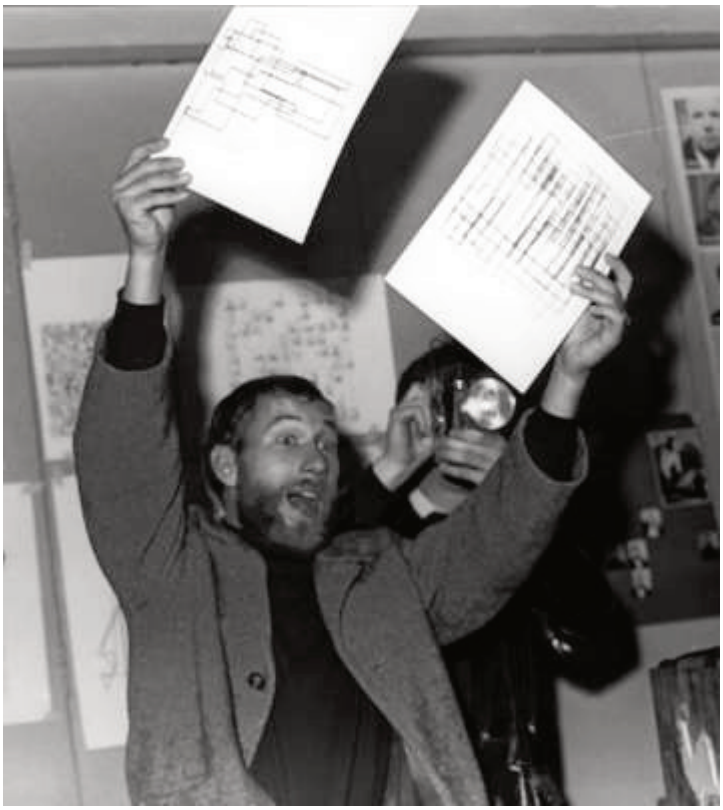
Herbert Franke



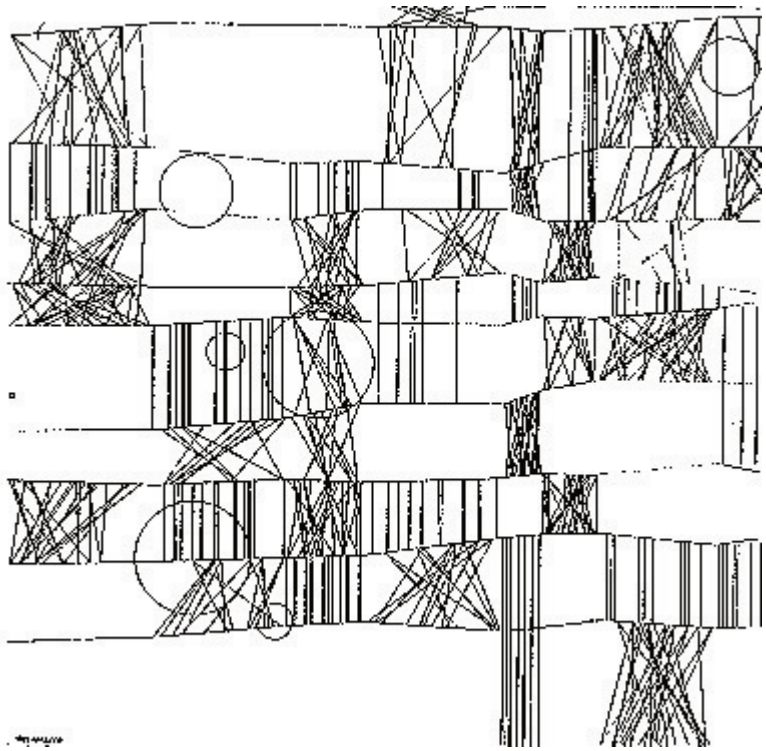
Herbert Franke


ELECTRONIC GRAPHICS BY HERBERT W. FRANKE

Frieder Nake



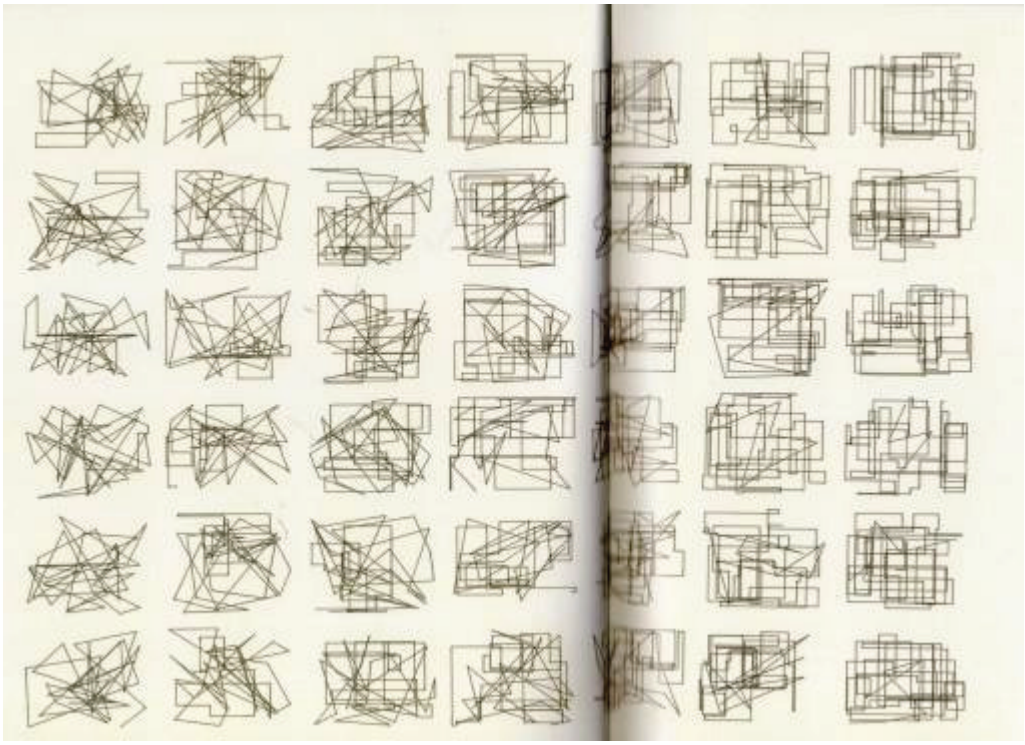
Frieder Nake



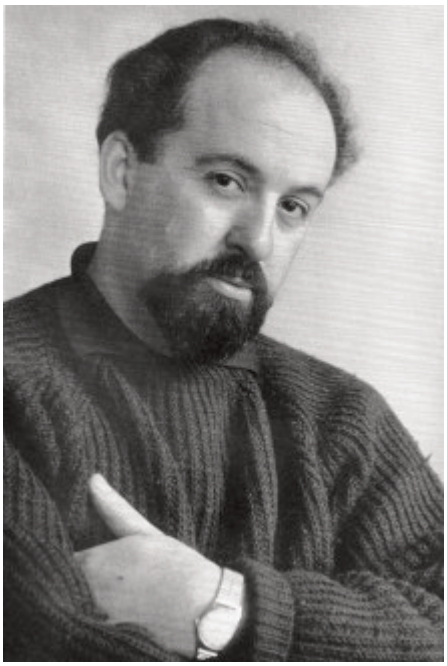
George Nees



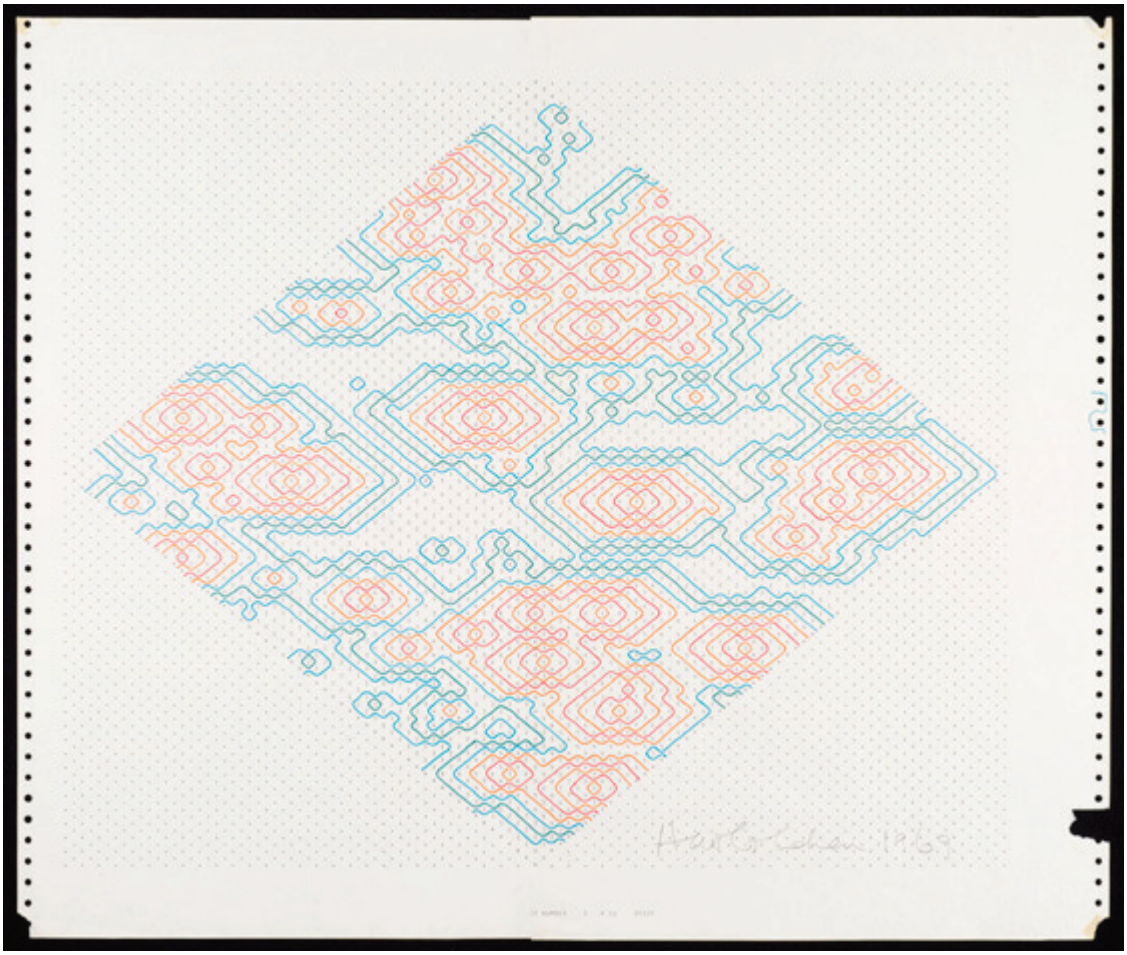
George Nees



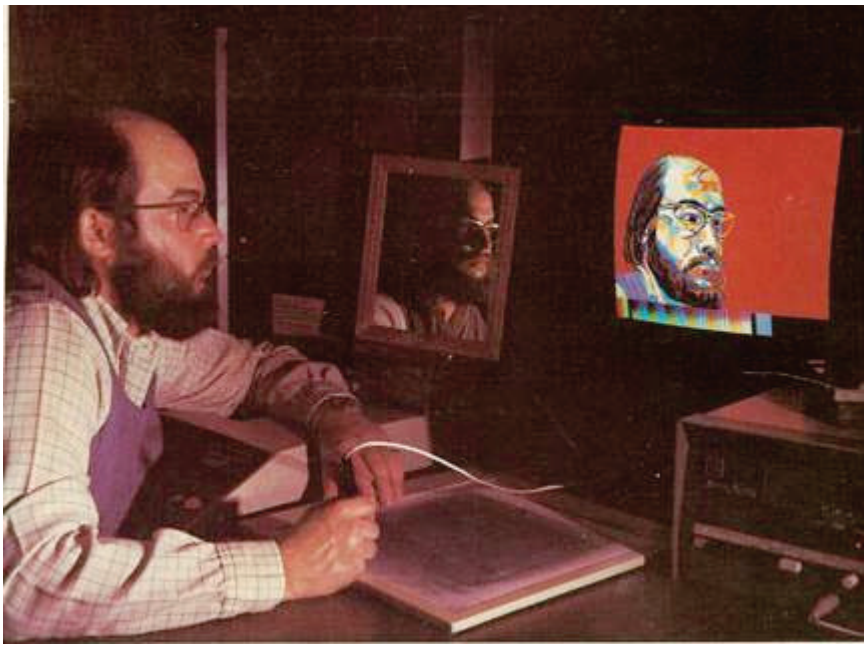
Harold Cohen



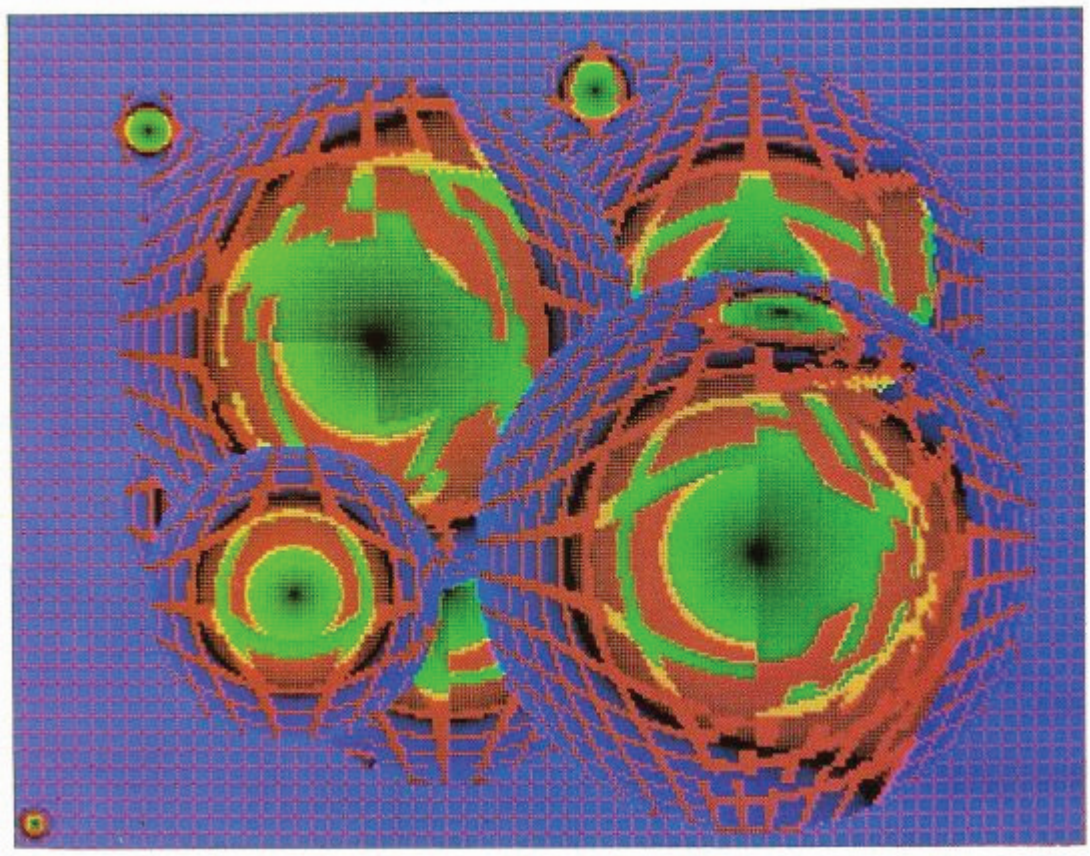
Harold Cohen



Duane Palyka



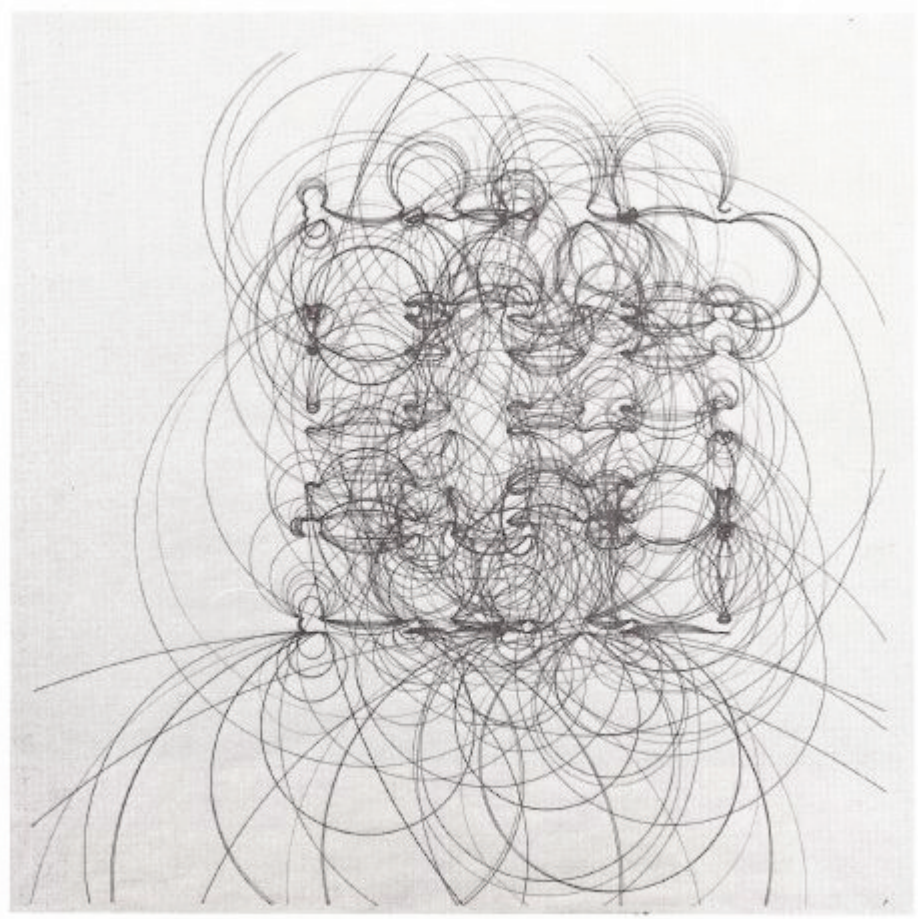
Duane Palyka



Colette and Charles Bangert



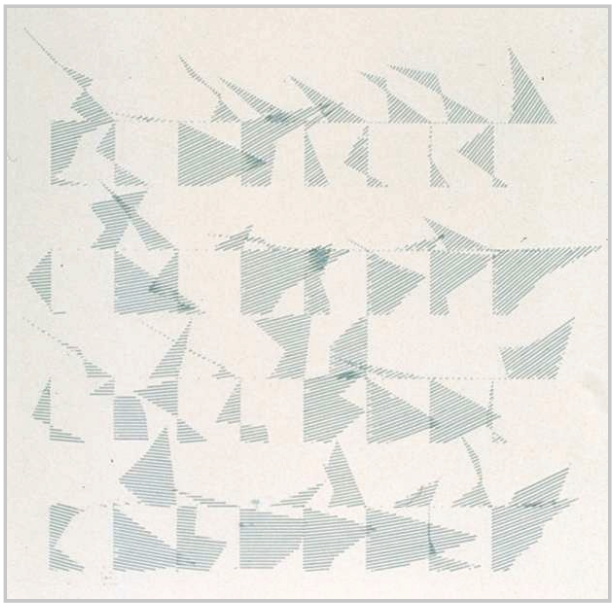
Colette and Charles Bangert

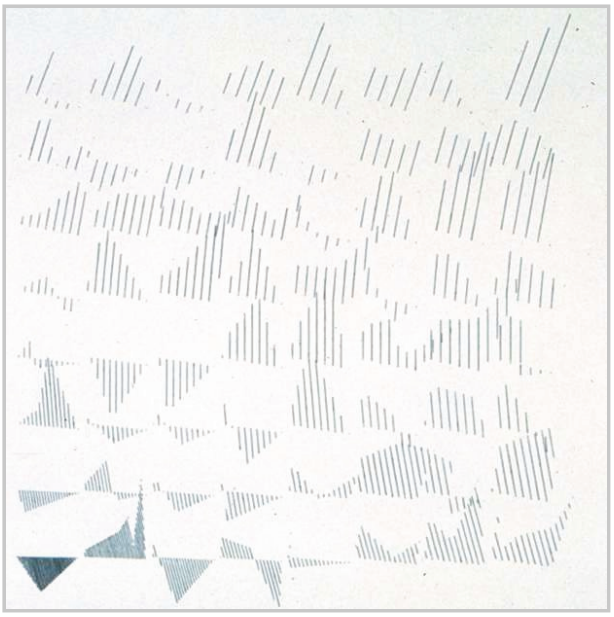


Joan Truckenbrod

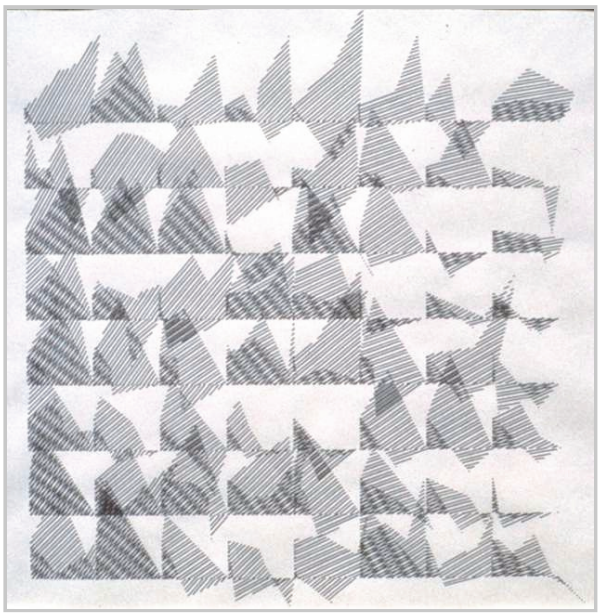


Joan Truckenbrod





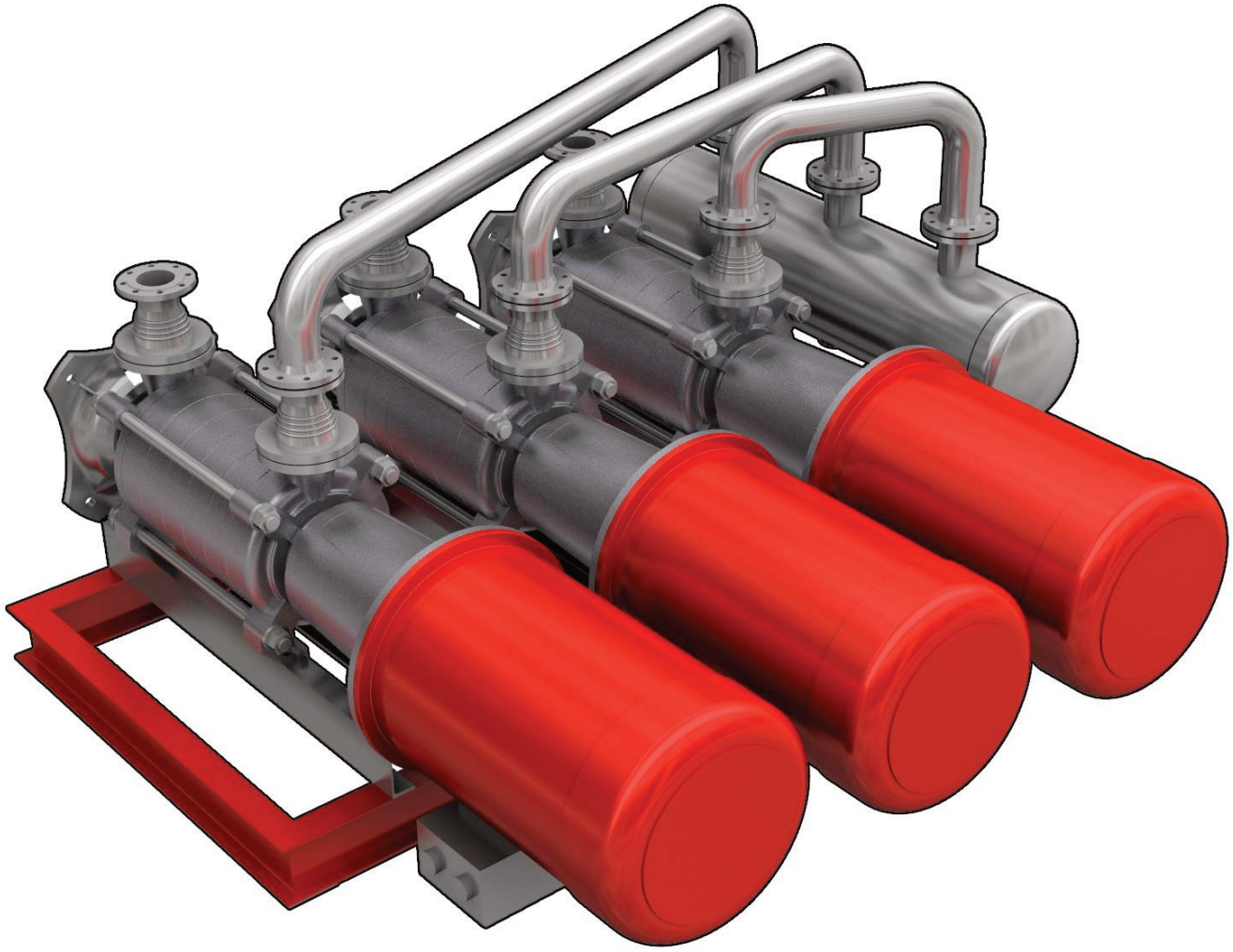




Chapter 10: CAD/CAM/CADD/CAE

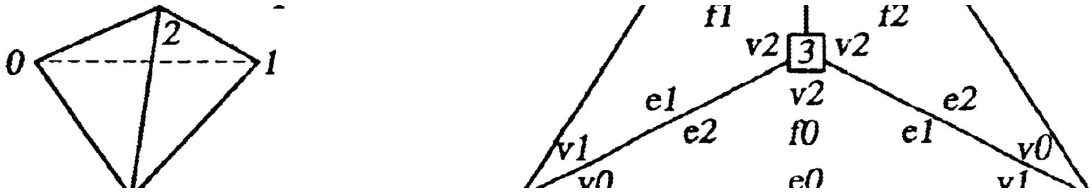
CAD/CAM/CADD/CAE

Computer-aided design software packages range from 2D vector-based drafting systems to 3D solid and surface modelers. They can be used for conceptual design activities, all the way through developing patterns for manufacturing.



CAD generated mechanical component

10.1 Introduction



As is the case with most of computer graphics, the Computer-Aided Design (CAD) discipline can trace its beginnings to the Sketchpad system developed by Ivan Sutherland in 1963. Sutherland was able to connect the display capabilities of the CRT, with the computational abilities of the computer, and the interactive process made possible with the light pen to create a system for designing mechanical parts. His system was described in a 1963 AFIPS conference paper. At the same conference, his advisor, Prof. Steven Coons of MIT published an article that laid out the relationship of the computer-aided design system as it evolved from the automatic programmed tool (APT) that was developed from the milling machine that was designed for use with the Whirlwind computer (both of these articles are referenced in the bibliography box at the end of this section.)

As was discussed in Chapter 2, the work of Sutherland prompted the automotive and aerospace companies to take notice and start their own projects to try to harness the power of the computer for their design needs. One of the most notable programs was the DAC (Design Augmented by Computer) project at General Motors (Chapter 3), which was a joint project with IBM. Two of the main individuals involved in this project were Fred Krull and Dr. Patrick Hanratty, whose contributions will be discussed later.



Apollo CAD system

The late 60s saw a flurry of activity in the CAD-related sector. Besides the turnkey companies described below, several other companies started creating and marketing software or hardware for this industry. David Evans and Ivan Sutherland founded Evans and Sutherland Computer Corporation (E&S), which was one of the leaders in high end graphics workstations used in the CAD arena. Other equipment was developed by IBM, Adage, GE, DEC, CalComp and others (see Chapter 3.) One of the main players at this time was Calma, originally a manufacturer of digitizers used in mapping and integrated circuit manufacturing. (In the mid-80s Calma was acquired by General Electric and then sold to Prime Computer.)

On the software side, MAGI released its SynthaVision solids software, which is considered by many to be the first commercial solid modeler program. Charles Eastman, at the Institute for Physical Planning at Carnegie Mellon, developed the *GLIDE* system with Max Henrion and the *General Space Planner (GSP) System*, a software system for solving space planning problems. Eastman and Kevin Weiler also published a seminal paper on the use of *Euler operators for geometric modeling*. Pierre Bezier and Steven Coons contributed important approaches to free-form surface applications for the CAD industry. The **CSG** modeler PADL-1 , and later PADL-2 were developed by the *Production Automation Project* at the University of Rochester. Bruce Baumgart introduced a data structure, called the *Winged Edge data structure*, that provided an efficient representation for 3D objects.

Pierre Bezier wrote of his*remembrances of the early CAD activities* in the IEEE Annals of the History of Computing in a 1998 issue.

Sutherland, Ivan, *SKETCHPAD: A Man-Machine Graphical Communication System*, AFIPS, SJCC 23 (1963), pp 329-346.

Coons, Steven, *An Outline of the Requirements of a Computer-Aided Design System*, AFIPS, SJCC 23 (1963), pp 299-304.

Definitions:

CAD – computer-aided design
The use of computer programs and systems to design detailed two- or three-dimensional models of physical objects, such as mechanical parts, buildings, and molecules.

CAM – computer-aided manufacturing
The process of using specialized computers to control, monitor, and adjust tools and machinery in manufacturing.

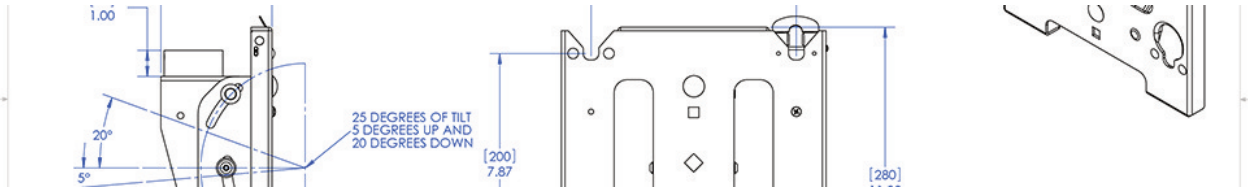
CAE – computer-aided engineering
Use of computers to help with all phases of engineering design work. Like computer aided design, but also involving the conceptual and analytical design steps.

CADD – Computer Aided Drafting and Design, Computer-Aided Design & Drafting, or Computer-Aided Design Development

The use of the computer to help with the drafting of product plans.
– The American Heritage® Dictionary of the English Language, Fourth Edition

CAD pioneer Joel Orr has developed a web site devoted to a community-based accounting of the history of CAD at *http://joelorr.squarespace.com/community-caddcam-history-proj/*

10.2 MCS / CalComp / McAuto



MCS

Patrick Hanratty's contributions began in 1957 with PRONTO, the first commercial numerical-control programming system. After the completion of the DAC program, Hanratty started his own company, focused on the development of integrated and interactive computer aided drafting, design and manufacturing. His company, MCS (Manufacturing and Consulting Services, Inc.) was instrumental in the early evolution of the commercial software CAD environments. In addition to selling products under its own name, in its early years MCS also supplied the CADD/CAM software used by such companies as McDonnell Douglas (Unigraphics), Computervision (CADDS), AUTOTROL (AD380), and Control Data (CD-2000) as the core of their own products. In fact, according to MCS web site, industry analysts have estimated that 70% of all the 3-D mechanical CADD/CAM systems available today trace their roots back to MCS's original code. The company's first product, ADAM (Automated Drafting and Machining), was released in 1972, ran on 16-bit computers, and was one of the first commercially available mechanical design packages. Dr. Hanratty founded United Computing in 1969. More will be said of United Computing contributions later in this chapter.

In 1976, MCS introduced AD-2000, a design and manufacturing system for the first 32-bit computers. In 1986 they introduced ANVIL-5000, a 3-D mechanical CADD/CAM/CAE system that, for over a decade, was the most powerful, fully integrated CADD/CAM/CAE software available, running on all classes of engineering computers from high-end workstations to personal computers.

CalComp

California Computer Products, Inc. (CalComp) was a manufacturer of digital plotters, disk drives and other "plug compatible" computer equipment. CalComp was incorporated Sept. 17, 1958, and introduced the world's first drum plotter (the Model 565) in 1959. They were involved primarily with the production plotters until about 1968, when they began selling disk drives manufactured by Century Data Systems of Anaheim, California. The legendary CalComp 1040-series pen plotter was introduced in 1984. For a while, CalComp distributed IsiCAD software, now owned by FIT Systems. CalComp was bought by Sanders Associates in 1980. In 1986, CalComp became a unit of Lockheed after the company purchased Sanders Associates.[1]



Engineers working with CalComp workstation

In 1973, CalComp filed a claim against IBM for preventing CalComp from competing in the disk drive market. The company claimed that IBM had monopolized the market through premature introduction of new central processing units and disk drives, price cuts on existing disk products, leasing policies and other unfair marketing practices over a period of ten years (1963 – 1972). The courts eventually ruled in 1977 that IBM's pricing, marketing and design changes did not constitute an attempt to monopolize the market.

McAuto

Because of its special internal needs, the aircraft industry has produced some of the world's leading CAD programs. These include proprietary software developed at Boeing, CADAM by Lockheed, McAuto by McDonnell Douglas and CATIA by Marcel Dassault in France.

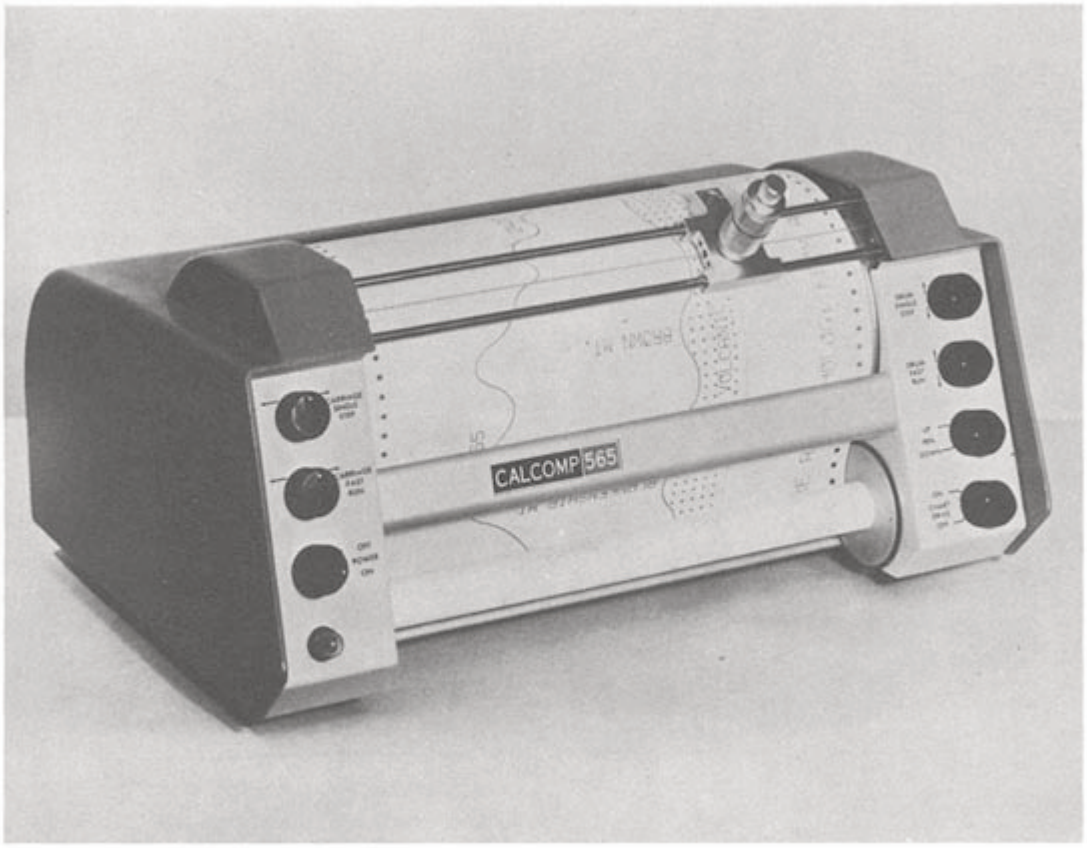
McDonnell Douglas Automation Company (McAuto) was founded in 1960. Their engineers closely watched the DAC program and the ITEK Electronic Drafting Machine optics design efforts, the latter resulting in the Control Data Digigraphics commercial CAD system. McAuto played a major role in CAD development with the introduction of the sophisticated CADD program. CADD was the primary product of McAuto, and it was only available on large IBM mainframes using expensive Evans & Sutherland Picture System display terminals. The software was optimized for the design of aircraft structural components, and even though CADD was possibly the most sophisticated CAD/CAM system available at the time, it had a few major problems that prevented it from being widely used. Besides the obvious reliance on very expensive hardware, McAuto was also prevented from selling CADD to anyone who might be considered a competitor of any of the various aerospace divisions of the parent corporation. The few commercial CADD customers included companies like Timex and Cessna Aircraft

1. Images from this section are from CalComp promotional documents or manuals.

(they built aircraft, but not in competition with MDC). The biggest non-MDC user of CADD was the Northrop Corp., but even they were restricted from using the software for anything other then the F-18 program, a joint development with McDonnell Aircraft. In 1976 McDonnell Douglas acquired United Computing, developer of the Unigraphics CAD/CAM/CAE system.

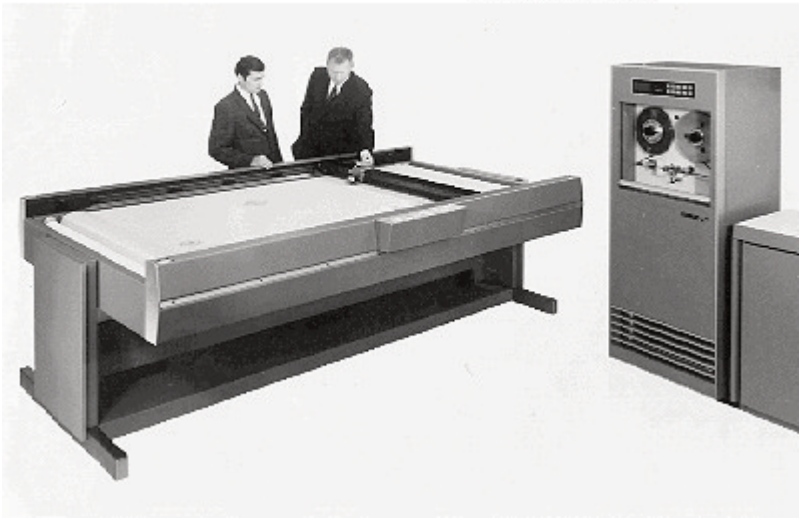


CalComp Workstation



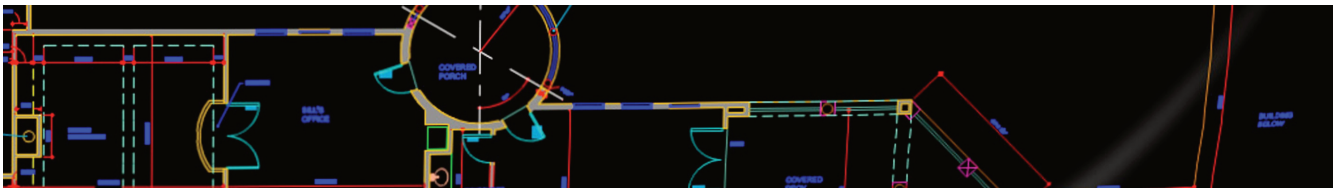
1. CalComp model 565, 12-inch drum plotter.

From Computer Desktop Encyclopedia
Reproduced with permission.
© 1996 CalComp, Inc.



CalComp 738 flatbed scanner

10.3 Auto-trol / Applicon / ComputerVision



Auto-trol

Auto-trol was one of several companies that crossed the Computer-Aided Design and Computer-Aided Design & Drafting boundaries. Established in the Denver area in 1962, Auto-trol's first product was a digitizer manufactured in the garage of the company founder, Bill Barnes. Mr. Barnes named the company Auto-trol as a shortened version of automated control, which he had called a product he developed in the 1950s. In its early years, Auto-trol manufactured hardware and software for drafting, marrying its original digitizer and flatbed plotter with minicomputers and display terminals.

In 1973, the Hillman Trust purchased Auto-trol. That same year, Auto-trol emerged as a pioneer in the fledgling CAD industry by announcing Auto-Draft, one of the first turnkey graphics systems available. Throughout the 1970s, the CAD industry expanded at a rapid rate, and Auto-trol expanded along with it. In January 1979, Auto-trol's initial public offering was completed. Also in 1979, Auto-trol became the first company to market technical publishing applications to be used to produce the complex technical illustrations needed for service manuals, parts catalogs, and engineering documentation.

Applicon

Fontaine Richardson was one of the first graduates of the University of Illinois computer science program, after which he went to MIT to join the Lincoln Labs group. In the summer of 1969, Richardson and three of his colleagues left Lincoln Labs and founded a company to commercialize computerized electrical engineering design tools. They called the new company Applicon. "Starting an application software company at the time was kind of crazy, kind of half-cocked," recalled Richardson. Only a handful of companies, including the Norden Division of United Aircraft, GM, and Lockheed, were doing this sort of work.

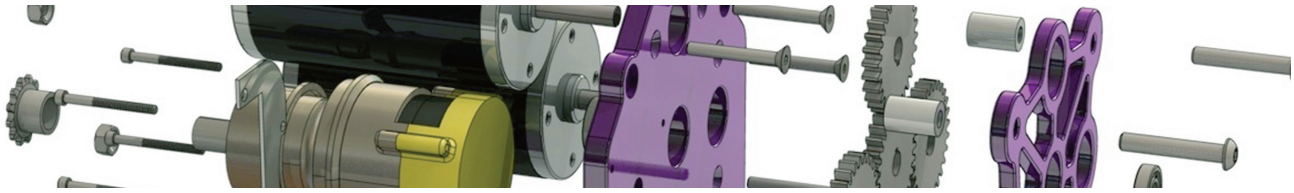
Applicon built a suite of four products: one was for designing IC photomasks, one was for digital circuit simulation, one was for frequency domain circuit synthesis, and one for microwave circuit analysis. All were

to be sold via timeshare, except for the IC photomask program, which required a stand-alone workstation or computer. They decided, because of economic concerns, to concentrate on the IC program, called the Design Assistant. Its first customer was Matsushita in Japan. The company grew from there, expanding to include printed circuit boards and hybrid circuits. Another package was added for three-dimensional designs (mainly for the automotive industry). They produced more and more applications, using the interactive screen design concept, and when Richardson left in 1980, after selling the company to Schlumberger and then merging it with MDSI which Schlumberger had acquired earlier, it was running at revenues of $100 million per year.

Computervision

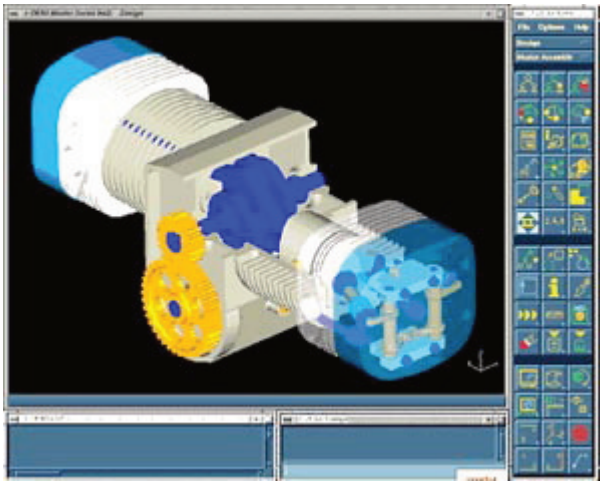
Computervision was created in 1969 to produce systems for production drafting and in the same year it sold the first commercial CAD system to Xerox. In 1978, Computervision introduced the first CAD terminal using raster display technology. In the late 1970s, Computervision made a costly decision to build their own computer system. Once the new 32-bit computer systems replaced the old systems, Computervision stopped their proprietary hardware development and switched to Sun Microcomputers. Prime Computer bought Computervision and their CAD software for mainframes and workstations in 1988. Just after the purchase Prime ran into financial trouble, canceling projects and making staff reductions. Prime tried to change into a UNIX workstation producer but the company was dying. VersaCAD Corp., previously known as T&W Systems, was also bought out by Prime Computer, Inc. In 1997, Computervision was purchased by Parametric Technologies, becoming a wholly owned subsidiary, and its CADDS 5 software joined the ?Pro/Engineer CAD/CAM/CAE software as a Parametric offering.

10.4 SDRC / Unigraphics



SDRC

In 1967, after leaving his teaching position at the University of Cincinnati's mechanical engineering program, Jack Lemon established the Structural Dynamics Research Corporation (SDRC). "I established the company to help solve problems that plagued manufacturers," said Lemon. "At the time, Computervision and Applicon were the software leaders, but they focused their efforts on the 2-D drafting marketplace. Our vision was to integrate design, **FEA (Finite Element Analysis**), testing, and systems to overall product design. We were among the first to integrate 2-D drafting with **CAE**. This effort prompted the need for solid modeling. This was the impetus behind Geomod, a product that provided capabilities to do FEA more efficiently to increase productivity."



Screenshot from SDRC Workstation

Later, while still with SDRC, Lemon's development team introduced Superb FEA, Modal Plus, a modal testing analysis and analysis program, and SuperTAB, the first commercial modeling package that ran on DEC workstations. SDRC first brought their products to market in the early 1970's. At that time, both Ford Motor Company and General Motors started using SDRC software for pre and post process analysis. SDRC first introduced their I-DEAS software in 1982. Developed by SDRC's internal product development organization, I-DEAS was created to address the growing MCAE (Mechanical Computer-Aided Engineering) marketplace.

In 1993, after eleven years of continued growth, SDRC introduced the I-DEAS "Master Series." This new generation of software products for mechanical design automation was completely reconfigured. Automotive

manufacturers in particular used I-DEAS to design any automotive component or assemblies that were beneath the Class 1 surfaces of an automobile. The product also proved itself valuable for designing other aspects of automobiles, such as drive trains, engines, transmissions, chassis components (such as brakes and suspensions, etc.), and seats. In addition to the automotive/transportation industry, I-DEAS was also used in aerospace and defense, electronics and consumer products, industrial equipment, and energy and process. But the lion's share of the users (and SDRC revenue) came from the automotive industry. In 2001 news was released that EDS intended to purchase all of the assets of SDRC. EDS wanted to build a new business unit around SDRC and their previous acquisition UGS, which continued to be known as UGS and operates as an EDS subsidiary.

Unigraphics

United Computing was founded by John Wright in Torrance, California. The first product released by United Computing was UNIAPT, which was a minicomputer based version of APT (Automatic Programmed Tool), a part programming language used to compute tool paths for milling machines. The unique thing about UNIAPT was that is was one of the first CAM products that was sold to the actual end users. Up until this time most companies created their NC programs using time-sharing services from large providers such as McAuto.

In 1973 United purchased the ADAM (Automated Design and Manufacturing) code from Hanratty's MCS. United paid for exclusive rights to the software for both the U.S. and the rest of the world, except for Japan. (However, Hanratty also sold "exclusive" ADAM licenses to both Computervision and Gerber.) MCS updated the software, calling it AD-2000. Licenses for AD-2000 were sold to Autotrol, Graftek, and Control Data, among others.

In 1973 the ADAM software was ported to a General Automation SPC-16 (an early 16 bit mini-computer) with a Tektronix display and an added menu-driven user interface. This was implemented as a single-user system and given the name Uni-graphics (the hyphen was removed in 1974). In 1981, Unigraphics introduced the first solid modeling system, Uni-Solids. It was based on the University of Rochester's PADL-2, and was sold as a stand-alone product to Unigraphics. It provided basic 2D modeling & drafting functionality and supported 14 layers. One of the selling points was that it was a graphical "front-end" for the UNIAPT system.

In 1976 United Computing was acquired by McDonnell Douglas. The company remained in Carson, California but was operated as a wholly owned subsidiary of St. Louis based McAuto, the Automation division of MDC. That same year the GRIP programming language was introduced. It was originally intended to address a request for support of parametric modeling. While it would be years before there were tools that adequately addressed this need, GRIP turned out to be one of the most popular and widely used modules ever offered with Unigraphics. For many years GRIP was considered by many customers to be the most significant differentiator between Unigraphics and the other CAD systems available.

After the problems with getting a stable version of Unigraphics released, McDonnell Douglas decided to close down United Computing and make formal financial arrangements with John Wright and the other founders. The remainder of the organization became part of the newly formed CAD/CAM division of McAuto.

In 1979 Unigraphics Solutions acquired Engineering Animation Inc. (EAI) of Ames, IA. EAI products included the line e-Vis and Vis-View software. EAI had been a longtime partner with Unigraphics Solutions, supplying tools used in Unigraphics' ProductVision software.

In 1988 Unigraphics acquired Cambridge, England based Shape Data Ltd. (developers of Romulus, Romulus-D, and Parasolid) and began commercializing the Parasolid kernel as a stand-alone product. Parasolid was an extremely powerful B-rep solid modeling kernel that allowed the joining of boundary represented surfaces together as a solid. In 1999 Unigraphics Solutions Inc. announced that it had reached an agreement to purchase Applicon, Inc.

10.5 Intergraph / Bentley / Dassault



Intergraph



Intergraph logo on building

In 1970 M&S Computing was founded by two engineers from the NASA space program. It became known as Intergraph (from Interactive Graphics) in 1980. Intergraph became a publicly owned company in 1981. In the beginning it was a consulting firm that supported government agencies in using digital technology. Among these technologies were application-oriented user interfaces that communicated with users in the language of their applications, rather than in programming terminology. The first Intergraph computer graphics system to apply these computing concepts was used by the federal government for designing printed circuit boards. Composed of unaltered stock parts from various vendors, the terminals consisted of a single-screen Tektronix 4014 display terminal with an attached keyboard and an 11-inch by 11-inch “menu” tablet that provided the operator with a selection of drawing commands.

Intergraph grew to be the largest computer graphics company in the world with about 100 offices worldwide and corporate headquarters in Huntsville, Alabama. Its flagship CADD product, IGDS (Interactive Graphics Design Software), was developed in the 1970's. In 1983 Intergraph started shipping InterAct and InterPro. InterAct, with its sculptured surfaces, won two of the three national design awards for new products. These terminals were powered by VAX and MicroVAX processors from DEC.



Intergraph Workstation



Intergraph Display (1978)

The terminals used microprocessors to control the display of the graphics image locally but still relied on the VAX processor to manage the Intergraph application products that created and manipulated the graphics database. Their first standalone workstation, the InterPro 32 was introduced in 1984.[1]

In the 1990s, Intergraph built their products around the PC, powered with Intel processors. Intergraph claimed that after several years of mutually beneficial work, in 1996 Intel began making unreasonable demands for royalty-free rights to Intergraph patents already being used in Intel microprocessors. When Intergraph refused, Intel abused its monopoly power by engaging in a series of illegal coercive actions intended to force Intergraph to give Intel access to the patents.



Intergraph Workstation (1981)

1. Images from this section are from Intergraph promotional documents or manuals.



Intergraph iPro

With no other source of suitable high-end processors available and with its hardware business under serious threat because of Intel's actions, Intergraph sought court protection by filing a lawsuit on November 17, 1997. The lawsuit asserted claims against Intel in three areas: illegal coercive behavior, patent infringement, and antitrust violations. Intel and Intergraph settled the suit in 2002. Under terms of the settlement agreement, Intel paid $300 million to Intergraph, the lawsuit was dismissed, the companies signed a cross license agreement, and Intergraph sold certain unrelated patents to Intel.

However, significantly impacted by Intel's punitive actions, Intergraph's ability to compete in the PC and generic server market was impaired. In 1999 Intergraph exited those businesses. Intergraph completed the exit from the hardware business by selling the Zx10 workstation and server product line to SGI and the graphics accelerator business (Intense3D) to 3Dlabs. Intergraph announced its intention to structure all aspects of the company around vertically focused business units that provided technical software, systems integration, and professional services.

In 2001 Intergraph again sued Intel charging Intel with infringement on two Intergraph patents that define key aspects of parallel instruction computing (PIC). This patented technology was developed by Intergraph in 1992 when the company's Advanced Processor Division was designing Intergraph's next generation C5 Clipper microprocessor. In October of 2002 Intergraph won that $150M lawsuit.

Timeline of Intel/Intergraph legal disagreements

1997 – After several years of mutually beneficial work, Intel began making unreasonable demands for royalty-free rights to Intergraph patents already being used in Intel microprocessors. Intergraph filed suit against Intel in an Alabama court, alleging patent infringement, antitrust violations, and illegal coercive behavior.

2000 – Due to Intel's actions, Intergraph was forced to exit the hardware design and manufacturing business.

2001 – Intergraph files suit against Intel for infringing on the company's Parallel Instruction Computing (PIC) patents.

2002 – Intel pays $300 million in an agreement to settle the 1997 Clipper patent case. Intel pays Intergraph $150 million to settle the 2001 PIC patent case.

2004 – Intel agrees to pay $225 million to the Intergraph Corporation to settle remaining claims that its Itanium chip infringed on Intergraph's patents. The settlement brings the total amount Intel has paid or will pay to Intergraph to $675 million.

Bentley

Bentley Systems, Incorporated was founded by Keith and Barry Bentley in 1984. The company's first product,

MicroStation was based on Intergraph's IGDS product and provided leading-edge CADD capabilities on a personal computer. Originally named PseudoStation, the software developed by Bentley Systems allowed users to view IGDS drawings files without needing Intergraph's software. In 1987, Intergraph Corporation acquired exclusive sales and marketing rights to MicroStation which became a worldwide standard for large-scale engineering projects on all platforms. After Intergraph purchased 50% of Bentley Systems, a new version of MicroStation added proprietary extensions to the IGDS and renamed it DNG. In 1994, the distribution arrangements were restructured and MicroStation marketing and sales were transferred back to Bentley, and the company grew from a software development house to a fully independent business. Their single MicroStation product has expanded into a broad family of over twenty products for plant engineering, building engineering, mechanical engineering, and GeoEngineering.

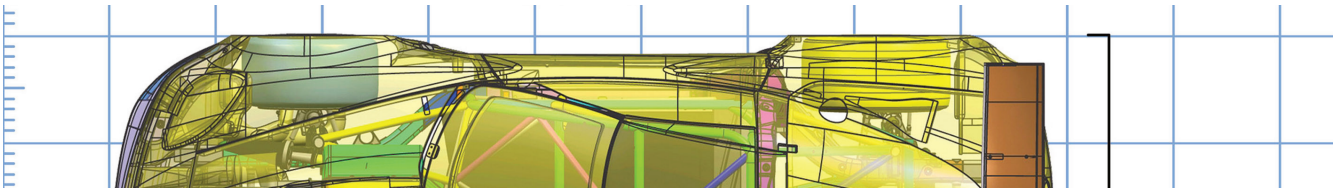
Dassault

In 1975 Avions Marcel Dassault (AMD), later Dassault Systemes, purchased CADAM (Computer-Augmented Drafting and Manufacturing) software equipment licenses from Lockheed, becoming one of the very first CADAM customers. By 1977, AMD assigned its engineering team the goal of creating a three-dimensional, interactive program, the forerunner of CATIA (Computer-Aided Three-Dimensional Interactive Application). Its major advance over CADAM was the 3rd dimension. In 1984 drafting capabilities were added to CATIA, enabling it to function independently of CADAM. By 1985 CATIA Version 2 contained fully integrated drafting, solid and robotics functions, making it the aeronautical applications leader. By 1988 CATIA Version 3 contained AEC functionality and was ported to IBM's UNIX-based RISC System/6000 workstations. CATIA thus became the automotive applications leader as well.

Founded in December 1993, SolidWorks Corporation introduced the first powerful 3D CAD software available for a native Windows® environment.The product was based on the Parasolid kernal. They have released new major product lines every year since 1995, most recently SolidWorks 2004 software, representing over 285,000 software seats to date. Solidworks received a U.S. patent for the SolidWorks FeatureManager™,now the standard CAD user interface found in every CAD application today.The company was acquired by Dassault Systemes in 1997 for $300M in stock. SolidWorks serves customers in industrial, medical, scientific, consumer educational, technology, and transportation markets.

In 1998, Dassault acquired the French Matra Datavision company, creators of the EUCLID systems for**free-form surface modeling**, NC control and injection molding simulation. The EUCLID Styler, Machinist, Strim and Strimflow products enhanced the CATIA product in these areas. They later partnered with IBM as a strategic international business partner.

10.6 Autodesk / Micro-Control Systems



Autodesk



Autodesk employees (founder John Walker in center)

Autodesk was founded in 1982 by John Walker. He and the other 15 co-founders set off to develop five different desktop automation applications. They did this with the notion that one of the applications would take off and be developed further. That product turned out to be AutoCAD, which was based on a CAD program written in 1981 by Mike Riddle called MicroCAD, changed later to Interact. It was shown at the COMDEX trade show in Las Vegas as the first CAD program in the world to run on a PC.



Autodesk products

AutoCAD is a Computer Assisted Design (CAD) software package for 2D and 3D design and drafting. It originally ran only on Microsoft operating systems. Versions for Unix and Apple Macintosh were released, but these met with limited market acceptance and were later dropped. Initially for mechanical engineers, it was extended and was very widely used by architects and other design professionals. Its file formats (DWG and its ASCII equivalent, AutoCAD DXF) became the default standard for CAD packages. Version 1.0 was released in December 1982.



AutoCAD running on PC

Software and the Generic CADD program.[1]

AutoCAD 2004 was released in March 2003. A lower-cost version, AutoCAD LT was first introduced in 1993. Compared with its more expensive sibling, LT lacked the AutoLISP programming language and other programming interfaces, some 3D capability, and a few other features.

In 1986 CADENCE magazine was established for the AutoCAD user community. It would become the world's largest independent CAD publication. In 1989 Autodesk purchased Generic



CADENCE magazine cover

Micro-Control Systems

In 1985 Peter Smith and Livingston Davies founded Micro-Control Systems and released CADKEY, the first 3D PC CAP product. 3D was still very hard to work with on a PC and it was not until a later release that CADKEY was able to become a serious player as a 3D wireframe layout tool and for drafting. That same year Diehl Graphsoft, Inc. was founded and the first version of MiniCAD was shipped. MiniCAD became the best selling CAD program on the Macintosh.

Some other relevant CAD items:

- In 1978 the Computer Graphics Newsletter, a two year old publication founded by Joel Orr, became Computer Graphics World magazine.
- In 1979 Boeing, General Electric and NIST developed a neutral file format as a contract from Air Space called IGES (Initial Graphic Exchange Standard). It became the industry standard format and the most widely accepted format for transferring complex surface information, such as NURBS curves (see Chapter 7 for more information.)
- CoCreate Software Inc., was established in 1984 as a division of Hewlett-Packard Company with the charter to expand the scope and focus for development of computer-aided design (CAD) and computer-aided manufacturing (CAM) software products. In 1996, CoCreate became a wholly-owned subsidiary of Hewlett-Packard Co. and expanded its product offerings to include collaboration software solutions
- In 1988 Martin Newell (formerly of the University of Utah) founded Ashlar Incorporation and released Ashlar Vellum CAD software.

1. The image at the header is a Corvette Racing Next-Generation C6.R. This CAD (computer-aided design) illustration shows the overall layout of the GT2 Corvette C6.R's components, with a GM small-block V8 engine mounted behind the centerline of the front wheels and a 6-speed sequential-shift transaxle between the rear wheels (Richard Prince/GM Racing Photo).

Chapter 11: CG Production Companies

CG Production Companies

Computer Generated Imagery, or CGI, became a mainstream product in the advertising, television promotion, and motion pictures special effects industries, and a new business model of production of this imagery was born from it.



Dolphins: The Ride, IMAX Ridefilms, Rhythm and Hues (1998)

11.1 Introduction



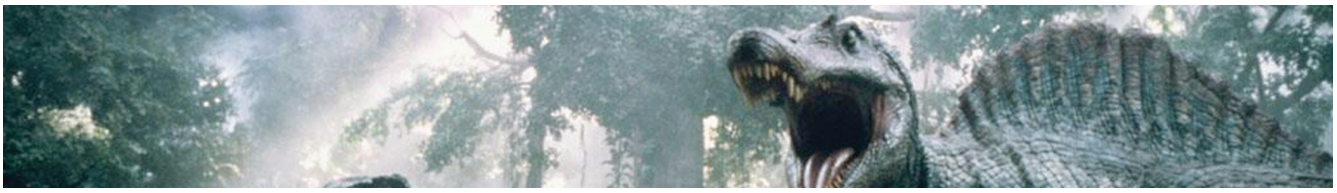
The year 1987 marked a very critical time in the history of computer graphics and animation production. Rapid and major changes in technology, in some cases coupled with some questionable business practices, resulted in the demise of a number of major graphics production studios, including Robert Abel and Associates, Digital Productions, Omnibus, and Cranston/Csuri Productions (already discussed in Chapter 6). At the same time, the work of these companies had raised the bar for image quality, and the advertising, television promotion and film industries were beginning to realize the impact of this new medium. Concurrently with these changes, and in some cases as a result of them, the industry reorganized itself into a major contributor to the rapidly emerging image synthesis market.

This chapter highlights some of the companies that were born of this time of change. Most of these companies attracted the significant talent that was a major part of the success of the folded enterprises listed above.

- ILM
- Pixar
- deGraf/Wahrman
- Metrolight
- Rez.n8
- Rhythm & Hues
- Kleiser Walczak
- Kroyer Films
- Sogitec
- R/Greenberg
- Lamb & Co.

- Xaos
- Blue Sky Studios

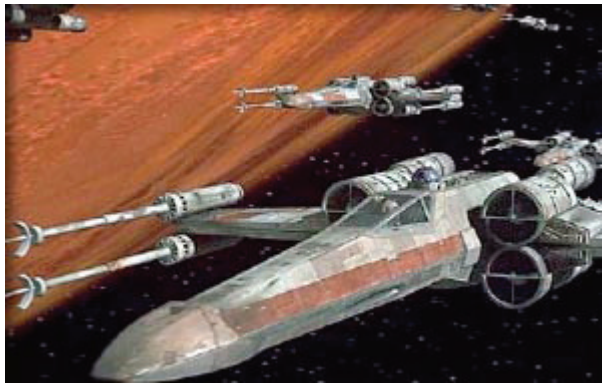
11.2 Industrial Light and Magic (ILM)



Lucasfilm Logo

George Lucas was born and raised in Northern California. He attended the University of Southern California film school. Always considering the Bay Area his home, Lucas returned to Northern California to pursue his film career. In 1971 he formed his own independent production company, Lucasfilm Ltd., in Marin County, just north of the Golden Gate Bridge.

In July of 1975, with the *Star Wars* saga already written and design work begun the previous year, Industrial Light & Magic (ILM) was established[1] to produce the visual effects for *Star Wars*. That same year Sprocket Systems was established to edit and mix *Star Wars*. It was later to become known as Skywalker Sound. In 1977 *Star Wars* opened and became the largest grossing film of all time to that date. It received six Academy Awards for original score, film editing, sound, art and set decoration, costume design and visual effects, as well as a Special Achievement Academy Award for sound effects creations.



X-Wing Fighter

With the release of *The Empire Strikes Back* in 1980 and a new home in San Rafael, ILM began to establish itself as the leader in visual effects production. The same year, ILM began to work on its first non-Lucasfilm picture, *Dragon Slayer*.

1. Portions excerpted from http://www.lucasfilm.com/inside/



Scene from The Abyss

Throughout the 1980s, ILM continued to receive recognition for its visual effects work, earning 10 Visual Effects Academy Awards during that decade. Included among the films honored are: *The Empire Strikes Back, Raiders of the Lost Ark, E.T. The Extra-Terrestrial, Return of the Jedi, Who Framed Roger Rabbit and The Abyss*. In *The Abyss*, ILM made further breakthroughs in computer graphics with its creation of the pseudopod, the first wholly computer-generated character [in a motion picture].

Skywalker Sound was also honored with 5 Academy Awards during this period for Best Sound and Best Sound Effects Editing on films including *The Empire Strikes Back, Raiders of the Lost Ark and E.T.* In 1987, construction was completed on the Technical Building at Skywalker Ranch, Lucas's film production facilities in central Marin, allowing Skywalker Sound to move into the 145,000 square-foot facility.'

Terminator 2: Judgment Day in 1991 was another milestone in the history of Lucas Digital. Additional advancements and achievements in the field of computer graphics were realized. Both ILM and Skywalker Sound were rewarded with Academy Awards for their work on the film.

In 1992 George Lucas was honored by The Academy of Motion Picture Arts and Sciences with the Irving Thalberg Award. This award is voted by the Academy Board of Governors to a creative producer whose body of work reflects a consistently high quality of motion picture production and is given only in years when the Board feels there is a deserving recipient. Steven Spielberg presented the Thalberg statue to Lucas at the Academy Awards Ceremony on March 30th.

The following year, in 1993, a new corporate structure was set up among Lucas's various companies to allow for management flexibility and accountability. Three separate companies were the result of the restructure:

- Lucasfilm Ltd. – Film and Television production,THX and Licensing/Toys
- LucasArts Entertainment Company – Games and Learning
- Lucas Digital Ltd. LLC- Industrial Light + Magic & Skywalker Sound



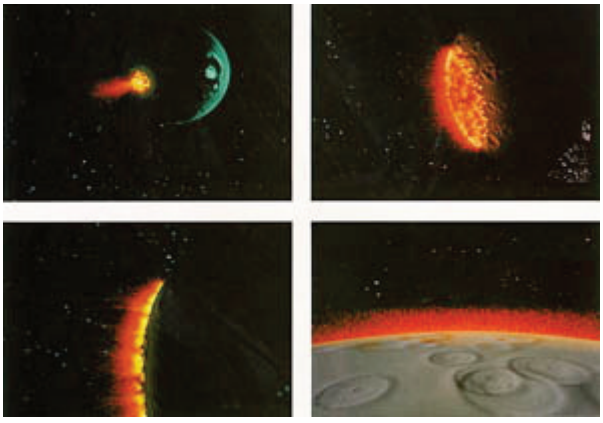
Kitchen scene from Jurassic Park

That same year, ILM completed the visual effects for *Jurassic Park*, creating computer graphic animals which blended flawlessly with the live action footage while Skywalker Sound was in charge of creating the audio effects. Again, both units were recognized with Academy Awards for their work in Sound, Sound Effects Editing and Visual Effects.

The nineties saw continued success and awards for both companies. Notable films that benefited from their expertise included *Forest Gump, The Mask* and *Twister*. In 1997, the twentieth anniversary date of *Star Wars*, all three movies in the *Star Wars* trilogy were rereleased. New and refined digital footage was inserted and the sound was enhanced. Record crowds greeted familiar characters with applause and delight and *Star Wars* once again became the largest grossing movie of all time.

Lucas hired effects expert John Dykstra to head a new production facility, located in old warehouses in Van Nuys, California. After completing *Star Wars* he relocated ILM to the Bay Area. They are located in San Rafael, California, but have several other campuses, including in the Presidio Park in San Francisco (information about the campuses can be found at ?*http://www.lucasfilm.com/inside/campuses/*)

After ILM finished *Star Wars*, Lucas contracted Triple-I for several CG effects tests, including animating X-wing fighters (Art Durinski and Gary Demos produced the tests) for *The Empire Strikes Back*. Lucas was impressed but couldn't come to contractual terms with Triple-I. Instead he made the decision to establish his own CG division, and recruited most of the researchers and management from NYIT, including Alvy Ray Smith and Ed Catmull, to staff the new division.



Frames from the Genesis Effect

The initial years were spent in research, developing film scanners and recorders, software for CG compositing, rendering architectures capable of film work, and computer assisted film and sound editing. The first production work came for the Genesis sequence for *Star Trek II, The Wrath of Khan* (see discussion in the Pixar section.)

Many of the CG team reorganized to form Pixar and Lucas reformed the Lucasfilm CG division as the ILM Computer Graphics Division, but as it grew in importance it became the prominent component of ILM, and the distinction as a separate name and division disappeared. Lucas Digital was the umbrella company for ILM and Skywalker Sound. The other Lucas companies were Lucasfilm, LucasArts, Lucas Licensing, and Lucas Learning.

In the early days of the company, they also established a CGI commercial production division. This group accounted for a large percentage of ILM's income during this time, but saw its importance diminish with a downturn in the economy and a cutback by customers for CG advertising work. As a result, ILM decided to close the department in mid-2002.



Stained glass Knight from Young Sherlock Holmes

The Lucasfilm Computer Graphics Group developed several industry leading hardware and software systems. The *Pixar Image Computer* was developed for compositing operations. The internal frame buffer was a special built hardware component that was controlled mainly by SUN machines and driven via command line. In 1984 it was used to composite the stained glass knight for the movie *Sherlock Holmes*. It was also coupled with the ILM built laser film scanner and recorder. They also developed a high quality renderer suitable for photorealistic film-resolution work. The scanline rendering algorithm was called REYES (Renders Everything You Ever Saw). The group developed shading trees which eventually became RenderMan's Shading Language.

One of the early images made by the group was called *Road to Point Reyes*. The rights to much of this ILM hardware and software technology was sold to Steve Jobs in 1986, as Pixar was founded (see next section).



Road to Point Reyes

The computer group associated with the graphics group developed a system to do film editing, which was called EditDroid. This development effort was headed by Ralph Guggenheim, who also came from NYIT. EditDroid was the first non-linear editing system. It was based on SUN hardware coupled with a laserdisc system and 3/4″ tape recorders. It had a custom touchpad used to make the cuts, and its interface used a timeline approach.

The SoundDroid was a similar custom computer system based on the Audio Signal Processor computer the group first built. It had an interface with a touchpad that permitted cutting and editing sound clips. Afterwards Lucas created a company called DroidWorks which would develop and sell these systems, but being custom solutions they were quite expensive. Eventually Lucas licensed and sold much of the technology to Avid in 1993.

Other innovations that have come out of the ILM efforts include:

- the expansion of morphing by Doug Smythe, based on the system first developed by Tom Brigham, formerly of NYIT, for use in the movie *Willow* (they received an Academy Technical Achievement Award in 1992 for the software *morf*)



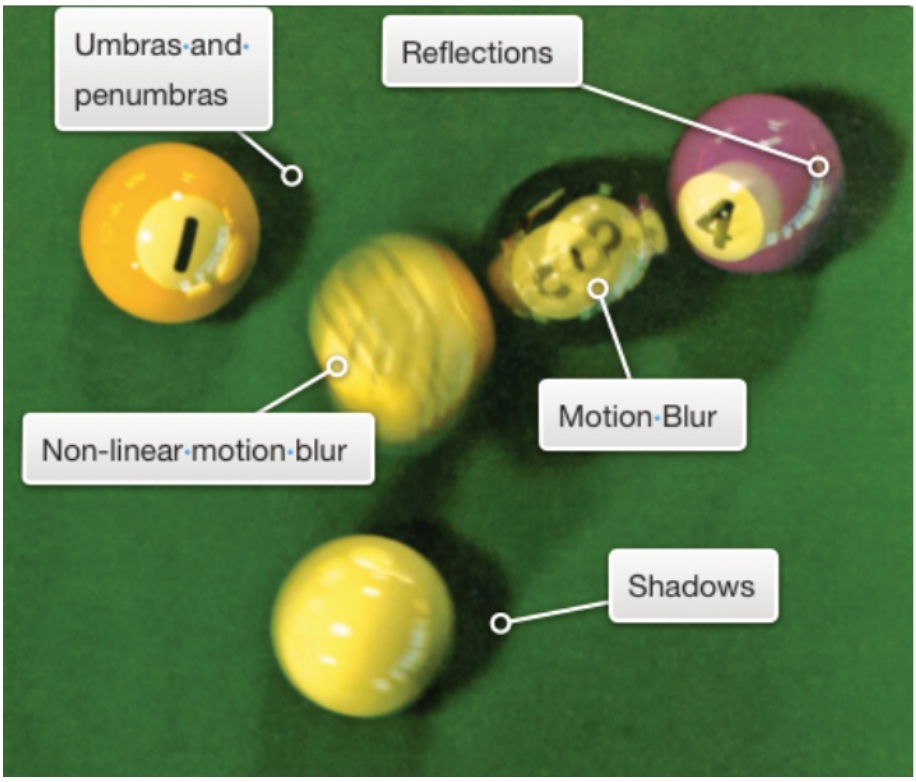
Poster for Willow

- The *Dinosaur Input Device* was later renamed the Digital Input Device or Direct Input Device. The DID was an armature, very similar to those ones used in **stop motion** but it also had electronic encoders at the joints. The encoders would translate the positions of the joints into the computer where the data could be used to move the skeleton of a CG dinosaur. The traditional stop motion animator could pose the armature (and hence the CG dinosaur) and set keyframes. ILM received an Academy Technical Achievement Award in 1996 awards for this development.
- John Knoll (who was a **motion control** technician) and his older brother Thomas Knoll (a PhD candidate at the University of Michigan doing work in image vision) developed Photoshop in 1987. It was designed for Macs, based on the functionality of the Pixar Image Computer, and was used on *the Abyss*.
- The group led by David DiFrancesco eventually developed a laser film scanner and recorder in one unit in 1980, and in 1983 the unit was incorporated into the Pixar Image Computer. The first project to use the system was *Young Sherlock Holmes*. Several other facilities were also developing film scanners including Triple-I, CFC, PDI and RFX. All the facilities were recognized with Academy Awards in 1994 for their pioneer work in film scanning.
- ViewPaint was ILM's proprietary 3D paint system. It allowed the user to paint color texture maps on 3D models, and also allows for the creation of displacement maps, transparency maps, specular maps, etc. ILM received an Academy Scientific and Engineering Award in 1996 for ViewPaint.
- Caricature is ILM's proprietary animation software, developed by Cary Phillips of the R&D group. It was developed to meet the challenges of the facial animation for *Dragonheart*. The tool became so successful that animators started it using more extensively, not only for facial animation but also all sorts of secondary animation, like the breathing and skin jiggling of the dinosaurs in *The Lost World*. Cary Phillips received an Academy Technical Achievement Award in 1998.

ILM has significantly influenced the entire CGI industry, through its innovative software and hardware research and development, its incredible film work, and also through the companies that have grown with former ILM people. Some examples of such companies are:

- Apogee was the FX facility created by John Dykstra, the original Star Wars supervisor. Dykstra decided not to move to Northern California and opened shop in the old ILM facilities of Van Nuys. There he worked on several projects: *Star Trek The Motion Picture*, *Firefox and Invaders From Mars*. In 1993 Apogee closed.
- After the completion of *Star Wars* Hoyt Yeatman and Scott Squires in 1979 founded Dream Quest Images. Some early projects included T*he Adventures of Buckaroo Banzai Across the 8th Dimension and Blue Thunder.* DQI was bought by Disney to serve as their in-house FX facility in 1994. Disney reorganized and brought together the CG group of Feature Animation with DQI and renamed them The Secret Lab in late 1999, which closed in 2002.

- Boss Film was founded by former ILM supervisor Richard Edlund in 1983. Some early projects included *Ghostbusters*, *Die Hard* and *Poltergeist 2*. Edlund closed the facility after its last two projects, *Air Force One* and *Starship Troopers*.
- Phil Tippett was the stop motion master at ILM. In 1983 he decided to leave ILM and work on his own in a facility that would eventually become Tippett Studio. Some early projects include *Dinosaur!*, *Robocop, and Willow*. Tippett Studio is located near Berkeley, California.
- Digital Domain was founded by filmmaker James Cameron, makeup FX wizard Stan Winston and former ILM President and GM Scott Ross. Some early projects included *True Lies* and *Interview With a Vampire*. DD remained the second largest FX facility and was located in Venice Beach, California, where they worked on both large film projects like *Titanic*, small FX films like *A Beautiful Mind*, countless commercials and special projects like *T2 3D*.
- Sony Pictures Imageworks was started as a small in-house FX unit for Sony Pictures. In 1995 Sony offered Ken Ralston a position as its president to lead the expansion of the effort. Many other ILMers followed, including Lincoln Hu (Director of Technology at ILM) who became Senior VP and Chief Technology Officer at Imageworks.
- While Weta Workshop was founded in 1986 by Dan Taylor, Weta Digital wasn't formed until 1993. Several former ILMers, including Wes Ford Takahashi traveled to New Zealand to setup the basics of the new digital division. Weta Digital worked on *Contact* and owner Peter Jackson's *Lord of the Rings*. For *the Two Towers* former ILM supervisor Joe Letteri joined the production as the supervisor.
- Former ILM CG artist Henry LaBounta joined PDI as their VFX supervisor in PDI's CAFE (Computer Animation and Feature Effects). CAFE worked in many VFX projects like *The Peacemaker* and *The Legend of Bagger Vance*, Steven Spielberg's *A.I. Artificial Intelligence* and *Minority Report*. Due to the success of *Shrek*, PDI decided to close CAFE and concentrate on feature animation projects and commercials.
- Many former ILM members have joined Electronic Arts, like supervisors Dave Carson, Henry LaBounta, and Habib Zargarpour, and top CG artist Jay Riddle.
- Other notable facilities out of ILM include Complete Pandemonium (Steve "Spaz" Williams and Mark A.Z. Dippé), FreedomZone (Ellen Poon), The Orphanage, formed by Rebel Unit members Stu Maschwitz, Scott Stewart and Jonathan Rothbart, Tweak Films (R&D Lead Jim Hourihan and TD Chris Horvath), Digital Fauxtography (Terrence Masson), and DVGarage (Alex Lindsay).



This image was created by the ILM Graphics Division to test the theories described in a famous paper by Rob Cook, Distributed Ray Tracing, and to make certain that they were production ready to use in the André and Wally B. movie they were preparing for the SIGGRAPH 84 film show.

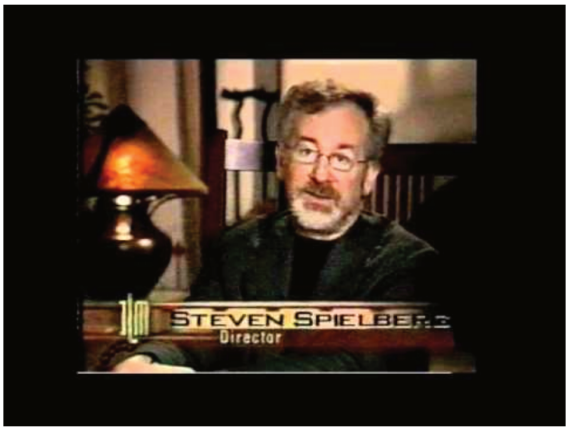


Frame from André and Wally B.



Frame from André and Wally B.

Movie 11.1 Star Wars to Star Wars



From Star Wars to Star Wars: The Story of Industrial Light & Magic (1999) – a TV documentary of the history of the company, hosted by Samuel L. Jackson? *http://www.youtube.com/watch?v=AFNTe7speqk*

Movie 11.2 Jurassic Park



Excerpted from "Industrial Light and Magic: Creating the Impossible" documentary.? http://www.youtube.com/watch?v=NxfxsjCR_-o

Movie 11.3 André and Wally B.



Alvy Ray Smith originally conceived the idea for this short, which represented André as a robotic style "android". John Lasseter was brought on to ILM to help realize the film, and he changed the character to a more organic form. It was rendered on the new ILM REYES system, which integrated ***motion blur****, a lighting approach developed by Rob Cook, a particle system plant generation approach developed by Bill Reeves, and a new animation system called Motion Doctor realized by Tom Duff. It was rendered on all of the VAX computers at ILM, some borrowed machines at MIT, and several Crays from Cray Research in Minnesota. a Mitchell camera filmed it one frame at a time from the monitor. It premiered at SIGGRAPH 84, with George Lucas and his the girlfriend Linda Rondstat in attendance.*
https://www.youtube.com/watch?v=C-L-WA-nQzI

Note: It was announced on October 30, 2012 that Lucasfilm, Ltd. including LucasArts, Industrial Light & Magic, and Skywalker Sound, would be purchased by Disney from George Lucas for $4.05B in cash and stock.

Disney Announcement from USAToday

The *Mac Rebel Unit* was a group within ILM that used Macs to do their jobs. Its name is taken somewhat jokingly from being a smaller band of "rebels" amid the large "empire" sized Unix and Linux based groups. The unit was started by Dennis Muren and was primarily composed of artists. Among the work that they did was painting of texture and image maps, digital matte paintings, some compositing, rotoscoping and even some 3D work. The Art Department and the *Star Wars* prequels pre-visualization unit were also Mac based. Among the tools the Rebel Mac unit used were Photoshop, Commotion and Electric Image. (From the*ILMFan.com* web site FAQ).

An excellent accounting of the development of Lucasfilms, including the efforts at NYIT that would ultimately become Pixar, can be found in the book Droidmaker- George Lucas and the Digital Revolution, by Michael Rubin, which is available as an eBook from the iTunes store.

An article written by Alvy Ray Smith in the IEEE Annals of the History of Computing, for their 1998 special on Graphics Remembrances, details the presentation by the CG effects team to convince George Lucas to utilize CGI in his films (*George Lucas Discovers Computer Graphics)*

The Reyes Image Rendering Architecture

Distributed Ray Tracing

The Making of the Genesis Sequence
(Video – http://www.youtube.com/watch?v=Qe9qSLYK5q4)

Stained Glass Sequence from *Young Sherlock Holmes*
(Video – http://www.youtube.com/watch?v=uOsxXi-tu_U)

The Visual Effects of Willow

Pixar Image Computer article

The Genesis Demo: Instant Evolution with Computer Graphics, Alvy Ray Smith, American Cinematographer (1982)

Links for Richard Edlund and Boss Films

- *http://www.callicosfx.com/Behind_The_Scenes/Boss_Films/boss_films.html*
- *Interview with Richard Edlund of Boss Films*
- *1997 NY Times Article*
- *1998 Dow Jones Article*

In late 1981, the home and arcade game company Atari approached George Lucas with a proposal to bring high quality graphics technology to the game design world, and in 1982 Lucasfilm and Atari joined forces.

Lucasfilms hired UNIX expert Peter Langston who assembled a team of programmers (including David Fox and David Levine) to work on two proof-of-concept prototype games, Ballblazer and Rebel Rescue (Rescue on Fractalus!). Loren Carpenter contributed an approach to generating fractal mountains, and the prototypes were so successful they became the first products of the new Lucasfilm Games division in 1984. The games were developed in the UNIX environment, and copies were leaked and appeared on a games BBoard before they were released.

http://www.atarihq.com/othersec/library/lucasflm.html

11.3 Pixar



PIXAR

Pixar logo

The origins of Pixar were at the heart of the graphics lab at NYIT. This group was largely moved to ILM after Lucas recruited Ed Catmull to develop a computer graphics group there in 1979. As was discussed in the previous section of this chapter, many innovative hardware and software technologies were developed at ILM, including what was called the Pixar Image Computer.

On February 3, 1986 Steve Jobs paid $5M to ILM to purchase the rights to the technology, and invested another $5M to capitalize a new company that could utilize the technology in production. The new company was called Pixar, Inc. ILM retained the rights to use the technology in house, and continued animation work there. The *Pixar Image Computer*, which was intended for the high-end visualization markets, such as medicine, was eventually sold to Vicom Systems for $2M (a *video* showcasing the Pixar Image Computer can be viewed at *http://www.youtube.com/watch?v=ckE5U9FsgsE*.) At that time, 18 Pixar employees were also transferred out.



Pixar image computer

According to Alvy Ray Smith in a series of documents on his *web site*, George Lucas decided to refocus his efforts, so Smith and Ed Catmull contacted several venture capitalist groups, and several individuals and/or companies (including a partnership of General Motors' EDS computer services company, owned by H. Ross Perot, and a unit of Dutch electronics conglomerate Philips NV) to try to find funding to finance the spinoff, before Jobs came forward with his investment.

Ed Catmull became head of the new company and Alvy Ray Smith became Vice President. Most employees of the division at ILM (40 in all, including Malcolm Blanchard, Loren Carpenter, Rob Cook, David DiFrancesco, Ralph Guggenheim, Graig Good, John Lasseter, Eban Ostby, Tom Porter, Bill Reeves, and others) left for *Pixar*.



A Simple Model of Ocean Waves ?A. Fournier and W.T. Reeves

The early years of the company were tough, from a financial perspective. The sales of the Pixar Image Computer were slower than anticipated, resulting in the Vicom sale. The cost of computing frames of animation (particularly for film) was still very high, so the company did animation for advertising, including fairly well-known CGI ads for Listerine, Tropicana and Lifesavers (several won Clio Awards.)

Movie 11.4 Listerine – 1994



Clio Award-winning ad created by Pixar, directed by Jan Pinkava (Geri's Game) and produced by Darla Anderson (A Bug's Life).
https://www.youtube.com/watch?v=48tIwbuctYQ

This commercial production effort by Lasseter's group kept a small revenue stream coming in to the company, but additional funding was needed. Steve Jobs continued to provide these needed funds by converting the equity of the employees who originally owned a percentage of the company, ultimately putting in $50M and becoming the dominant stockholder.[1]

In 1990 Pixar moved their headquarters to Richmond, just across the bridge from San Rafael in Marin County. In 2002 they again moved, this time to a large campus on 15 acres in Emeryville. A description of the Emeryville HQ of Pixar from the architect's web site can be found *here*.

Image production during these formative years also included work on animated *short film productions*, most notably *Luxo Jr.* (1986), *Red's Dream* (1987), *Tin Toy* (1988), *KnickKnack* (1989) and *Geri's Game* (1997). Pixar won Oscars for *Tin Toy* in 1988 (*Luxo Jr.* was nominated in 1986) and Geri's Game in 1998.

1. Alvy Ray Smith documented the history of Pixar in an article called *Pixar History Revisited - A Corrective*, in which he takes on the myths that Jobs started, or bought Pixar. http://www.alvyray.com/Pixar/PixarHistoryRevisited.htm

Software created by Pixar in the first few years (or expanded from that developed at the ILM division) included the REYES (Renders Everything You Ever Saw) renderer, CAPS (developed for Disney), Marionette, an animation software system that allowed animators to model and animate characters and add lighting effects, and Ringmaster, which was production management software that scheduled, coordinated, and tracked a computer animation project. The film recording technology mastered by David DeFrancisco was incorporated into a new laser film recorder called *PixarVision*.

The applications development group also worked to convert the REYES technology to the RenderMan product, which was commercialized in 1989. Saty Raghavachary, a graduate of Ohio State's graphics program and a software developer at Dreamworks, summed up the development clearly in notes for a course on RenderMan at the Siggraph 2006 conference:

> The researchers had the explicit goal of being able to create complex, high quality photorealistic images, which were by definition virtually indistinguishable from filmed live action images. They began to create a renderer to help them achieve this audacious goal. The renderer had an innovative architecture designed from scratch, incorporating technical knowledge gained from past research both at Utah and NYIT. Loren Carpenter implemented core pieces of the rendering system, and Rob Cook wrote the shading subsystem. Pat Hanrahan served as the lead architect for the entire project.

The architecture embedded in RenderMan was presented in a paper by Cook, Carpenter, and Ed Catmull at Siggraph 87. [2] ACM SIGGRAPH Computer Graphics, Volume 21 Issue 4, July 1987, Pages 95-102, and the shader was documented in a 1990 paper by Hanrahan and Jim Lawson. [3]. The system was used in the creation of the Academy Award winning *Tin Toy* in 1988. A sequence of images, which has become quite famous, was created to demonstrate the capabilities of the software, and the stages of the rendering pipeline. Called the "Shutterbug" series, it has been used countless times to teach students the concepts of rendering.

RenderMan, or Photorealistic RenderMan (PRMan) as it is properly known, is actually a formal specification, or an interface description to provide a standard for modeling and animation programs to specify scene descriptions to rendering software. In February, 1989, nine months after Pixar promoted the scene description language, InfoWorld magazine announced the commercialization of the RenderMan imaging technology. Autodesk was the first licensee, wanting to include it in their AutoShade product. [4]

The group received Academy Technical Awards in 1992 for CAPS,1993 for RenderMan, 1995 for digital scanning technology, 1997 for Marionette and **digital painting**, and 1999 for laser film recording technology.

Steve Jobs discontinued the applications development effort in 1991, ostensibly because of a fear of competition with the NeXT product development efforts. As a result, nearly 30 people were laid off, including Alvy Ray Smith, who with two others then founded Altamira, with support from Autodesk. This reduced the total number of employees to about its original number of 40. At that point, the developers who were working on CAPS for

2. Cook, Rob, Carpenter, Loren, and Catmull, Ed. The Reyes Image Rendering Architecture,
3. Hanrahan, Pat, and Lawson, Jim. A Language for Shading and Lighting Calculations, ACM SIGGRAPH Computer Graphics, Volume 24, Issue 4, September 1990, Pages 289-298
4. In their July, 2013 issue, *fxguide* magazine published an interview with Ed Catmull and Loren Carpenter on the 25th anniversary of the release of the RenderMan 3.0 interface. It can be read online at https://www.fxguide.com/featured/pixars-renderman-turns-25/ A podcast of the interview with Ed Catmull accompanies the article at https://www.fxguide.com/fxpodcasts/fxpodcast-257-pixars-ed-catmull/

Disney and Photorealistic RenderMan, and Lasseter's commercial animation department were all the employees left at Pixar.

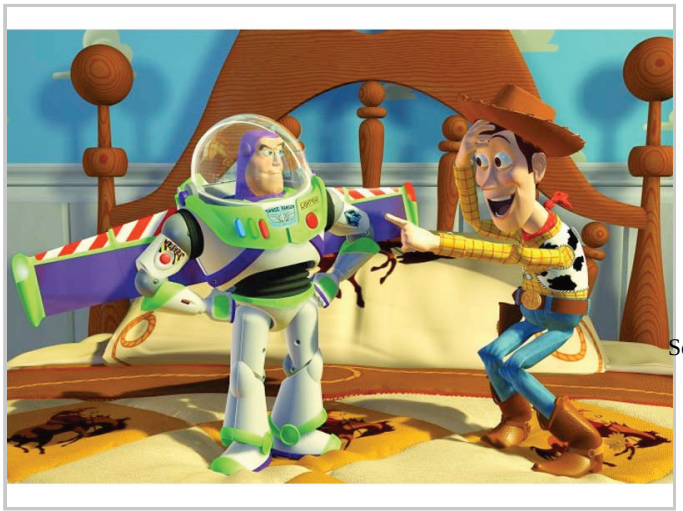
At that point, Disney executives and the leadership team at Pixar signed a $26 million deal with Disney to produce three computer-animated feature films, the first of which was *Toy Story*. In an *article in Fortune Magazine* Brent Schlender reported

> In 1991, Lasseter felt the Pixar technology was robust enough to make an hour-long computer-animated TV special. He pitched the idea to Disney, hoping the big studio would help fund the project. Jeffrey Katzenberg, who was running Eisner's film business, was already enamored of Lasseter's style. (Now a principal of DreamWorks, Katzenberg contends that the director is Pixar's biggest asset.) Katzenberg and Eisner came back with an unexpected counteroffer: How about making a full-scale movie that Disney would pay for and distribute?
>
> Not surprisingly, Jobs, who'd been absorbed by the trials and tribulations at Next, suddenly started paying more attention to his other company. He got involved in the negotiations with Disney, and hired one of Hollywood's most respected entertainment lawyers to help hammer out a deal. The result was a contract for Pixar to make three feature films. Disney would pick up most of the production and promotion costs, as long as it had complete control over marketing and licensing the films and their characters. Pixar would create the screenplays and the visual style for each picture and receive a percentage of the box-office gross revenues and video sales.

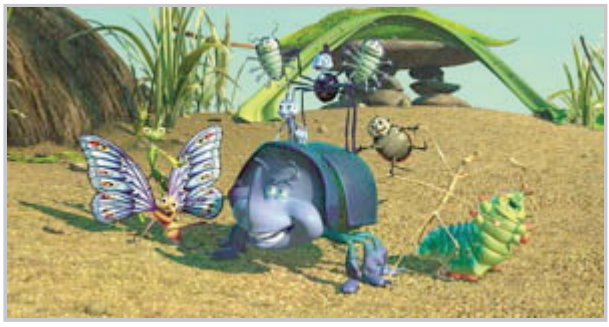
Jobs has to be given a lot of credit for sticking with the company. At several points, he considered selling it (it is reported that one potential buyer was Microsoft), but he ultimately realized, as *Toy Story* was wrapping up and Disney confirmed a Christmas release, that the company had tremendous potential and backed away from the desire to sell it.

In 1995 Pixar went public with an offering of 6,900,000 shares of stock. Shares opened at $47, more than double their offering price of $22, and at the closing price of $39 per share, the company had a market value of about $1.5 billion.

After successes with *Toy Story*, the Pixar interactive group developed two CD-ROMs, but were refocused in 1997 in order to concentrate the corporate effort on making films. In 1997 the two organizations (Pixar and Disney) announced a five picture agreement, including a sequel to *Toy Story.* Pixar produced the 1998 animated feature *A Bug's Life*, which set box office records, *Toy Story 2, Monsters, Inc. and Finding Nemo*.



Scene from Toy Story



Scene from A Bug's Life

Pixar and Disney went through a period of several public

disagreements, particularly around the production and quality of *Toy Story 2*, as well as Disney's ownership of story and sequel rights, and Jobs' not so quiet disdain for Michael Eisner. They attempted to come to an agreement, but both companies held firm on their demands. Pixar's contention was reported in the media:

> Pixar had complained that the terms of the distribution deal were tilted too heavily in Disney's favor. Under the deal, Pixar was responsible for content, while Disney handled distribution and marketing. In exchange, Pixar has split profits with Disney and pays the studio a distribution fee of between 10 percent to 15 percent of revenue. Based on its blockbuster success, Pixar has argued that it should keep the profit itself and cut the fees its studio partner charges.

Talks broke down in 2004, and Wired Magazine reported that *Pixar Says Goodbye to Disney*. Following that, Jobs reportedly entered into distribution discussions with Time Warner, Sony and Viacom, though no agreement was settled on. Talks with Disney resumed after Eisner left Disney in 2005.

Disney announced in early 2006 that it had agreed to buy Pixar for approximately $7.4 billion in an all-stock deal. Jobs gained a seat on the Disney board of directors and gave him 7% ownership. Lasseter, became Chief Creative Officer of both Pixar and the Walt Disney Animation Studios, as well as the Principal Creative Adviser at Walt Disney Imagineering, which designs and builds the company's theme parks. Catmull retained his position as President of Pixar, while also becoming President of Walt Disney Animation Studios.

Movie 11.5 Luxo, Jr.



The iconic Luxo lamp is manufactured by Luxo ASA, an Oslo, Norway based company. The lamp stands as Pixar's most famous symbol, was the subject of their 1986 produced short Luxo, Jr., is used in their movie opening sequence logo, and an oversized statue of the lamp graces the entry courtyard of their headquarters in Emeryville, California. https://www.youtube.com/watch?v=6G3O60o5U7w

The collection of short films, trailers and outtakes produced at Pixar can be seen at their corporate website

at
http://www.pixar.com/short_films/Theatrical-Shorts

Home Designing.com has a photo tour of the Pixar headquarters at
http://www.home-designing.com/2011/06/pixars-office-interiors-2

An interview with the Pixar executives can be viewed at
http://www.youtube.com/watch?v=YjSExqtiIyg

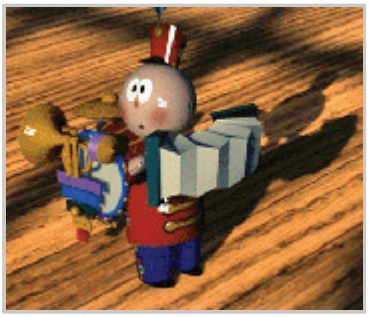
Gallery 11.1 Frames from Pixar Shorts



Luxo, Jr.



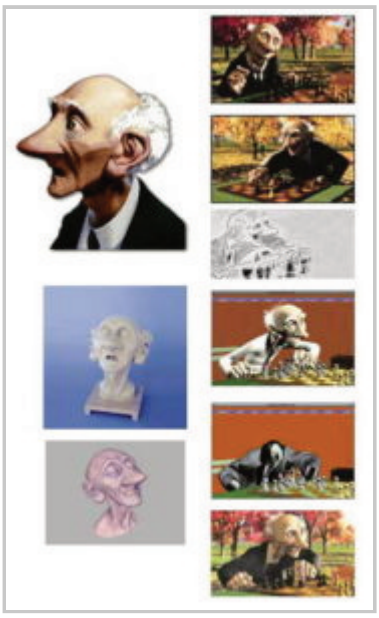
Red's Dream



Tin Toy

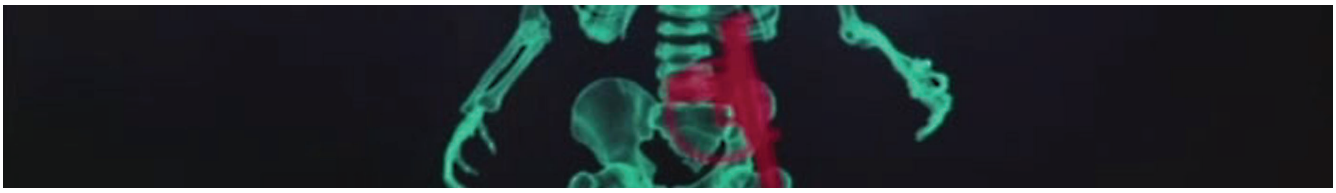


Knick-Knack



Geri’s Game

11.4 Metrolight / Rezn8



Metrolight



Metrolight Logo

Founded in 1987 by James Kristoff (former President of Cranston/Csuri Productions), Mits Kaneko (JCGL), and Dobbie Schiff (former Director of Sales at Cranston/Csuri Productions), MetroLight brought many experienced animators and designers to work on projects in film and television. Originally called Northern Lights Studios, the company started in the former Robert Abel & Associates facility in Hollywood, with some of the old Abel equipment and a number of former Abel and CCP employees (including Tim McGovern, Doc Baily, Neil Eskuri, Al Dinoble, Con Pederson, Jim Hillen, Jim Rygiel (Abel), Steve Martino, Mark Steeves, Jon Townley, and Tom Hutchison ?(C/CP).)



Scene from World of Discovery

The company used SGI 3130 workstations and Wavefront software, as well as the equipment obtained from the Abel operation when they closed. After developing their own code to supplement and later supersede the capabilities of Wavefront, they opted to integrate the Alias and Maya code into their pipeline.

Beginning work in broadcast television (they continued a relationship with some clients that they had at CCP), they expanded into theaters with a series of computer animated trailers for AMC Theaters.

These spots, featuring the character “Clip”, gave the cinema chain a distinctive “look” and began its long business association with MetroLight. MetroLight made a

mark in feature film with 1990's *Total Recall*. The project required animating "skeletons" as characters passed through a futuristic security device capable of detecting anything from a weapon to a slipped disk. The effects were directed by Tim McGovern (who worked at Abel on *Tron* and *Brilliance*, and later helped found Sony Pictures Imageworks).

Originally planned to utilize motion capture, the scene had to be reconsidered after the data from the capture session was found to have some integrity problems. Instead, the studio rotoscoped film that was shot in low light during the capture. Tim and Metrolight won an Academy Award for their work on the Skeleton X-ray sequence in that film, which once again involved human motion and CG characters. The work was recognized for the fluid and realistic motion of the film's nine humans and one dog.



Scene from Total Recall

While continuing work in commercials and film, Metrolight explored the possibilities of CGI in music videos and interactive software. They also worked in the location entertainment field, with productions for theme park rides, and experimented with CG for games. They also wrote the 2D MetroCel software, under the direction of Mits Kaneko, who ran a very successful 2D production company in Japan. The **ink and paint** software, called Annie, was developed by the MetroCel division, headed by former C/CP software developer Mark Steeves. It was was used for the *Ren & Stimpy* TV series, and was later sold to Michael Milken's 7th Level. Steeves and Martino also left for 7th Level when the software was sold.

Movie 11.6 Metrolight demo

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/metrolight91-1.m4v

Commercial demo reel from Metrolight Studios in Los Angeles

Rez.n8 Productions



Paul Sidlo

ReZ.n8 was formed in 1987 by Paul Sidlo (formerly creative Director at Cranston/Csuri Productions) and Evan Ricks. They quickly gained a reputation as a world leader in conceptualizing, designing and producing state-of-the-art computer graphics, animation and special effects for major corporations and the entertainment industry, including broadcast, theatrical and commercial markets. ReZ.n8 won numerous awards, including Emmys in 1995 and 1998 for the NFL on Fox Sports graphics and in 1992 and 1994 for broadcast design for the CBS Olympic Winter Games. ReZ.n8 received BDA Awards in 1996 for designing the Pro-Sieben web site and in 1997 for CBS Sports content graphics. ReZ.n8 was nominated for a 1998 BDA Award for its work as the sole provider for all graphics used in the CBS telecast of the 1998 Olympic Winter Games.



Rezn8 Graphics

ReZ.n8's production manager supervised computer generated effects work for such large-scale productions as *Titanic*, *The Fifth Element*, and *Dante's Peak*. They had a fully integrated computer production environment featuring a state-of-the-art Windows NT network, which they received much attention around, as well as Mac and Unix networks and top-of-the-line SGI servers. Clients previewed the results of their work in a state-of-the-art multimedia facility, which featured a high-definition projection theater, surround sound and real-time interaction.

For many years, ReZn8 produced the on-air graphics for the Olympics. The magazine *Digital Studio* featured them in a 1998 *cover story*

In 2010 ReZn8 was purchased by Stereo Vision Entertainment, Inc.

Gallery 11.2 AMC Theaters (Metrolight)



“Clip” Artwork by Bill Selby



‘Clip” from AMC promotion



AMC Theaters Promo

11.5 deGraf-Wahrman / Kroyer Films



deGraf/Wahrman

DeGraf/Wahrman was founded in 1987 by former Robert Abel & Associates employee Michael Wahrman and former Digital Productions director **Brad deGraf** after the folding of DOA. Tom McMahon of Symbolics helped finance the company and provided equipment and software, including a Symbolics 3600 and the suite of S-software.

Brad deGraf studied architecture at Princeton and Mathematics at the University of California at San Diego. He started his career as lead software designer and programmer at SAIC for the US Army National Training Center, and became Head of Technical Direction at Digital Productions before opening deGraf/Wahrman and serving as Director of Production. After deGraf/Wahrman, from 1992 through 1994, he was Director of Digital Media at Colossal Pictures, which he and his partners spun off to create Protozoa.



Mike Normal

deGraf and Wahrman created Mike Normal, or “Mike the Talking Head”, the first live performance of a virtual character. It was shown live at the Electronic Theater at SIGGRAPH 88 in Atlanta. deGraf also created “Moxy” on the Cartoon Network, the first virtual character for television, and Peter Gabriel’s Grammy award-winning video, “Steam”.



Scene from Peter Gabriel video Steam

Theme park work included “The Funtastic World of Hanna-Barbera”, for Universal Studios Florida, “Journey to the 4th Dimension”in Japan, and “Robocop: The Ride” for Iwerks Entertainment Turbo Tours. He also worked on numerous feature films. He later was founder, and CEO of Dotcomix.



Moxy

Michael Wahrman worked in computer animation research and production since 1982. He worked at Robert Abel and Associates, where he helped design the production system and engineered the development of the raster system used for *High Fidelity*. Wahrman worked with Craig Reynolds of Symbolics on the SIGGRAPH 87 film *Stanley and Stella – Breaking the Ice*, which featured the Boids software developed by Reynolds. Wahrman was awarded an Academy Award for Scientific and Technical Merit for his contributions to the Wavefront Animation System.

His motion picture credits include *Starship Troopers, Event Horizon, What Dreams May Come*, and the Dream Pictures Studio full-length animated feature film *Hopper*. He was the senior visual effects advisor on the rebuild of the Hayden Planetarium and to the Digital Galaxy Project of NASA

From a 1988 Computer Graphics World article:

> Mike the talking head is a step towards animators being able to directly control their characters rather than drawing their actions. Silicon Graphics and deGraf-Wahrman Inc are working together to produce a new type of animation tool to allow animators to work with their characters in the same manner as puppeteers work with puppets.?The two companies hope to produce a real time, full rendering system with the ability to take input from different sources. The input will be able

to change the expression of the character as well as it's colour and the materials it is made out of. The image will be able to be scaled, rotated and distorted, and will be able to mouth words.?To create the original face to work with, a real person, Mike Gribble, was used as a model. His face was scanned in using a 3D digitizer to get about 256,000 points of digital data. These points are converted to polygon data which makes shading of the image possible. To give accurate data without redundancy, the polygons were smaller in areas which required greater detail and larger in the flatter areas, like the cheeks.?The talking component of Mike was achieved by scanning in the real Mike as he mouthed each phoneme. Phonemes are the subparts of words used in pronunciation. To simulate speech, the implementors developed code to interpolate between phoneme positions. Possible input devices include data gloves and speech recognition systems. The glove could be used in a similar manner to a puppeteers hand inside a puppet. The speech recognition system could have Mike mouthing the words as a person speaks into a microphone.

Robertson B. (1988) *Mike the talking head*.
Computer Graphics World 11, (7): 57.

Dotcomix: Capturing Animated Motion On The Net, by Lee Dannacher, Animation World Magazine – Issue 5.03 – June 2000

Steam – Peter Gabriel music video
(Video – https://www.youtube.com/watch?v=Qt87bLX7m_o)

Stanley and Stella: Breaking the Ice
(Video – http://www.youtube.com/watch?v=3bTqWsVqyzE)

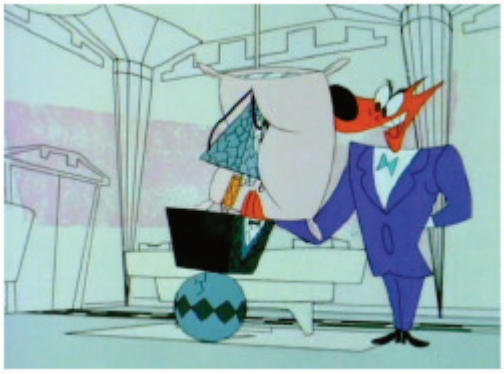
Kroyer Films



Kroyers

Founded by Bill and Sue Kroyer in 1986, Kroyer Films specialized in combining CG and hand animation. **Bill Kroyer** worked as a traditional animator for Disney in the late 70s and worked with Robert Abel and Associates in 1982.

The studio produced such projects as the animated feature film, *FernGully*, *The Last Rainforest* for 20th Century Fox, the 1988 Academy Award-nominated short film *Technological Threat* and the title sequences for *Honey I Shrunk the Kids*, *Troop Beverly Hills*, *National Lampoon's Christmas Vacation* and the *Making of Me* for the World Health Pavilion at Epcot Center in Disney World, and the TV series UltraCross.



Other employees of Kroyer included Kendra Haaland (Disney – *Hercules*) and Kevin Bjorke, who went to ILM and earlier worked with Kroyer at DP/Abel.

Technological Threat

From the SIGGRAPH 89 Panels, here is a short slide presentation by Bill Kroyer on the making of Technological Threat

Interview with Bill Kroyer Creating the Memories, from Animation World Magazine, April 1996

Movie 11.7 Technological Threat



https://www.youtube.com/watch?v=PLAGn3isH4o

11.6 Rhythm and Hues / Xaos



Rhythm and Hues Studio

Rhythm & Hues Studio Logo

Founded in 1987 by former Abel and Associates employees John Hughes, Keith Goldfarb, Charlie Gibson and Pauline T'so, and Omnibus technical director Larry Weinberg, R&H was one of the most reputable CG firms in the industry and a leading producer of character animation and visual effects for the entertainment industry. The company's work was prominently featured in movies, commercials and theme park attractions.



Babe

Based in Marina del Rey, California, the studio's facility was a creative home for more than 300 artists and staff. In 1995, Rhythm & Hues was honored with the Academy Award for Best Visual Effects for its work on *Babe*, named one of the Top Ten films of the 1990's by the Associated Press. The Commercial Division was well known for its work on the Mazda *Cool World* commercials, as well as the Coca Cola *Polar Bear* campaign. The studio was the recipient of top awards from both national and international competitions including the CLIOS, The New York Festivals, the International Monitor Awards, Monte Carlo's Imagina Awards and The Emmy Awards. In addition, R&H received two Scientific & Technical Academy Awards.



Coca Cola Polar Bears

Their facility housed live action and animation directors, animators, painters, modelers, producers, programmers, writers, technical and production support. They contributed work for the *Nutty Professor, Spawn, Mouse Hunt, Babe, Waterworld, Batman, Ace Ventura, Bedazzled, Little Nicky, Fighting Like Cats and Dogs, Red Planet, the Sixth Day* and others. They also contributed shots to *Hollow Man* (Sony), *X-Men* (Fox), *Frequency* (Lead house, New Line) and *Fantasia 2000*, for Walt Disney Studios. They are also well known for the Coca Cola bears that raced into our TVs during the Olympics, as well as the theme park rides Seafari and the Jetsons at Universal Studios, Florida.

Besides their film, television and theme park work R&H produced 3D CG for games, including *Eggs of Steel* for PlayStation.

In 1999 R&H bought VIFX, and former Abel employees Richard Hollander rejoined Richard Taylor and Bill Kroyer.

http://www.rhythm.com

Movie 11.8 Ads from R&H

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/RHads-2.m4v

Several ads from R&H (1988)

Movie 11.9 Making of Coca-Cola Bears

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/makeBears-1.m4v

Rhythm and Hues produced the innovative polar bear sequences for ads from Coca-Cola. This video depicts the making of one of the ads.

Xaos

Founded as Eidolon by Arthur Schwartzberg and Michael Tolson, it was renamed Xaos in 1989. Tolson's software development was key in the look of the company's work that was organic looking images of high complexity.



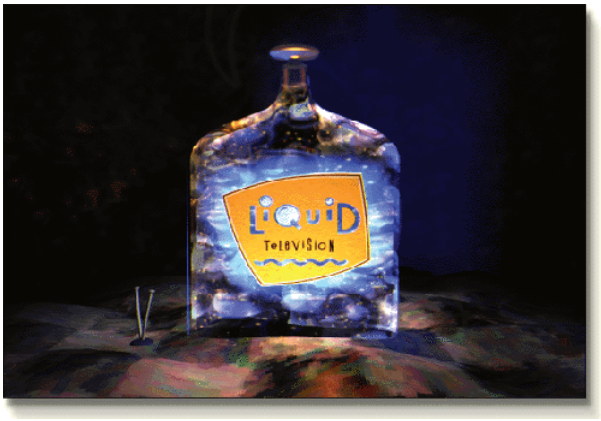
Scene from Lawnmower Man

Their most recognized production was of sequences in the 1990 film *Lawnmower Man*; they also produced a number of exquisite scenes for the MTV Liquid Television series. The look of the latter images was reminiscent of the products marketed by Xaos Tools, a not-so-successful Tolson/Schwartzberg spinoff.

Xaos, who unlike many of their peer companies of the time, was largely a Windows NT based company. Other work included animation for *The Pagemaster*, a Grateful Dead music video titled *Infrared Roses* and IDs for MSNBC and the Sci-Fi channel.

The following article about the company was from a news release by Intergraph – *Xaos Theory: The Science of Particles, Pixels, and Profits at Xaos, Inc.*

The word “Chaos” is not the first thing that comes to mind when you visit Xaos , Inc. in San Francisco. The spacious, high-ceiling facility resembles a well-kept artist’s loft with lots of natural light – a welcome departure for animators accustomed to working in darkened cubicles. In this cheery environment outfitted with Intergraph TDZ 2000 workstations and RenderRAX renderers, Xaos animators have produced some of the industry’s most compelling content for commercials, broadcast, feature films and large-format cinema.



Liquid Television promotion frame

Xaos was the creative force behind the Emmy Award-winning works ” Liquid Television MTV,” and MSNBC’s station IDs, as well as a long list of memorable commercials for major clients such as Nabisco, Sprint, Kellogg’s, and MasterCard. Film projects include the title sequence for Jumanji and ground-breaking visual effects for Lawnmower Man. Xaos is also emerging as the premier content creator for large-format 70mm films, including CG work on Everest and other IMAX features for National Geographic and Discovery Channel Pictures. ? ?*Thinking Big* ?”Creating content for IMAX and other large-format films puts your entire system to the test – from the workstations to the network to the renderfarm. The benefit of using Intergraph’s TDZ 2000 and RenderRAX is that we don’t have to trick anything out to work in that resolution.” — Michele Frazier, executive producer of commercials and broadcast, Xaos , Inc.

Xaos worked on a total of seven large-format films in the last year – an impressive number considering that only 175 of such films have been produced in the entire 28-year history of the format. Among Xaos’s accomplishments in the field include the CG sequences in Everest, a production whose Hollywood blockbuster-style profits have ignited new interest in large-format films. After the success of Everest, large-format companies such as IMAX, once relegated to producing science and nature documentaries, are working to take large-format out of the museums and into a multiplex near you.

Thinking Big

Creating content for large-format films places tremendous demands on Xaos’ workstations, networks, storage, and renderfarm. Each 70mm frame is composed of 4096 x 3003 pixels – four times that of standard 35mm film. The frames render out to a huge 48 MB per frame, while stereoscopic 70mm doubles disk and bandwidth requirements by requiring a separate image for each eye.

Xaos handles the task using Intergraph TDZ 2000 workstations connected to a **render farm** of Intergraph RenderRAX modules via a 100base-t switched network. Each multiprocessor RenderRAX unit is equipped with 1 GB of memory –

almost a bare minimum for rendering large-format frames, according to Mark Decker, technical director at Xaos . “If you have a texture that’s going to fill the entire 4K-pixel frame, the texture has to pretty close to 4K pixels or you’re not going to see enough detail,” he explains. “So we have to load a lot of our large textures into RAM all at once while we’re rendering them.”

The tremendous success of Everest has inspired even staid institutional filmmakers to introduce more dramatic elements into their films, and computer animation is seen as one way to do that. Xaos has taken this as an opportunity to position itself as not just as a service house, but a creative collaborator who helps the client understand the digital medium and recommend how it can be used. “We often advise clients on shots, beyond just giving them a bid and quote, but actually working with them on the script,” says Christina Schmidlin, executive producer of feature films at Xaos , “It makes it more interesting to us, and provides added value to the client.”

And Now a Word from Our Sponsor…
“The commercial marketplace is important to us because it keeps you sharp – it’s very demanding and can be very problematic. Landing a commercial project sends an electric shock through the facility. It’s like – ‘Incoming!!!’” — Arthur Schwartzberg, president, Xaos , Inc.

To keep their artistic edge and diversify their client base, Xaos seeks a balance between commercial projects and large-format films. Unlike large-format projects, which often begin planning six months to a year before production, commercial projects move through at light speed, according to Arthur Schwartzberg, president of Xaos . “With commercials, you get a call and they say, ‘We’re doing a project, we’ve narrowed it down to five houses, send your reel’, says Schwartzberg. “Then they call you the next day and say ‘OK, we’ve narrowed it down to three, let’s have a conference call!’ A day later you may (or may not) get the job, and it’s due in two weeks. It’s a lightning bolt.”

To strengthen relationships with commercial clients, Schwartzberg is expanding Xaos’ network of reps, being careful to choose people that understand the visual effects business. “Most reps are typically more live-action oriented because they represent live action directors,” he explains. “It’s important to us that they’re experts in visual effects so they can represent our work more effectively.”

In the high-stakes, high-pressure environment of commercial production, Schwartzberg considers his close relationships with Intergraph, Kinetix, and other vendors to be crucial strategic assets. Xaos has had plenty of time to nurture these relationships, as one of the first CG companies to abandon the Unix platform and move totally to Intergraph and Windows NT. “In retrospect, it was visionary,” says Schwartzberg, “But at the time, it was a very bold move.”

It’s a move that Xaos never regretted. “With Intergraph – I don’t know if it’s southern hospitality or what – but the whole company is infused with an attitude of value-added assistance,” he says. “That’s the kind of thing you can’t know when you’re shopping for systems. The box is cool – you buy it. But you don’t really know until later what that value-added service and attitude might be.” Richard Marco, systems administrator at Xaos , found out to his satisfaction. “I’ve been able to count on Intergraph for any kind of assistance. I’ve been extremely happy with the support. As the lone system administrator at Xaos , that makes my life a lot easier.”

The Particulars of Particles
“Intergraph’s TDZ 2000 is well designed in terms of the overall system design. The data flow is very efficient so you’re not wasting as much time moving data around within the system. Other than that, what can you say? The graphics are incredible, the drivers are solid, and the machine never crashes.” — Mark Decker, technical director, Xaos , Inc.

Xaos was an early pioneer in developing **particle animation** engines, and was the creator of a famous sequence entitled “Wet Waltz,” which features a dancing character that throws off droplets of water in all directions while swirling through the scene. One of the most powerful features of Xaos’ particle system is the ability to manipulate particles with a variety of forces after they are emitted from an object. Xaos is using this ability on a current IMAX project, in which animations are used to show how currents move in the ocean as they hit an underwater mountain. The effect is achieved with an off-screen rectangle emitting particles that simulate water flows. Xaos animators use the particle engine to populate the scene with various forces to make the currents bend, curl, and twist in vortexes as they hit various parts of the geometry in the scene.

Several years ago, Xaos integrated their proprietary particle code into a plug-in for 3D Studio MAX, providing a smooth user interface that artists can interact with. “Before we made it a plug-in, the software was very powerful, but not always very intuitive for the artists to work with,” says Mark Decker, technical director at Xaos . “Now you can see the object

emitting particles. You can move the object around while viewing the forces that affect the particles. It's much more intuitive than writing scripts."

On the other hand, Xaos engineers are not limited by the user interface. Their ability to access the code to achieve unique effects for clients is a competitive asset for the company and a key to their signature look.

Getting Down to Business
?"This business is tough. It's exciting, it's sexy, it's cool, its artistic – but it's tough. My attitude is 'Who wants to just struggle along?' We're taking a more aggressive stance about our future." — Arthur Schwartzberg, president, Xaos , Inc.

Arthur Schwartzberg has that unique combination of talents required for running a successful content creation business. He's part visionary, part businessman, part artist, part salesman. One of the founders of Xaos , Schwartzberg left in 1991 to form Xaos Tools, a software company. Last year Schwartzberg returned to Xaos with a Steve Jobs-style mission to refocus the company after a few "Xaotic" years. Apparently, Xaos's artistic vision was as sharp as ever, but some of the business aspects had been allowed to founder. "Like any business, you have to produce quality work, but that's not enough," explains Schwartzberg. "You also have to be proactive in sales and marketing, and when I first returned to Xaos , there was very little of that going on."

According to The Roncarrelli Report on computer animation, the CG industry continues to enjoy huge growth, but only a few companies have significant profits to show for it. Schwartzberg intends to remain among those few. He has aggressively maneuvered Xaos into a position to bid on much larger projects, some of them with multimillion-dollar budgets. The company is also looking at ways to move into content ownership – a practice unheard of a few years ago, but becoming an increasingly viable option for CG houses such as Xaos . "Until now, we've been a 100% service bureau – we do the job, we get paid, it's in the can, we move on to the next job," says Schwartzberg. "Owning a stake in the content is a way to go beyond that treadmill."

Xaos is finalizing a deal in which the company will serve as visual effects producer and coproducer on a large-format film project. Under the arrangement, Xaos discounts a percentage of their fee in exchange for an equity investment in the film. By doing so, the company hopes to establish more ongoing benefits in the form of royalties, ownership, and branding.

When it comes to computer hardware and software, Schwartzberg doesn't believe in cutting corners. "Our business is incredibly labor intensive — we spend 65% of our resources on labor," he says. "So if you have to spend a few thousand dollars more on technology that can boost your productivity – I consider that purchase to be intelligent and cost-effective." Consequently, Xaos' next hardware purchase will be top-of-the-line Intergraph workstations with Wildcat 3D graphics.

Schwartzberg reflects on how quickly the industry has changed in just a few years, when "high-end" was synonymous with proprietary Unix-based systems. "There was a time when we would never even think of using Intel-based systems – it would be embarrassing to tell that to a client," admits Schwartzberg. "Interestingly, nobody ever even asks anymore – it's become a complete non-issue. They just say 'send us your reel.' "

Movie 11.10 Scenes from Lawnmower Man

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/lawnmower-1.m4v

11.7 R/Greenberg Associates / Blue Sky Studios



R/Greenberg Associates

Started by Robert Greenberg and his brother Richard in 1977, ?R/Greenberg Associates[1] made a CG name for itself “flying” the opening titles for *Superman*.



Superman opening title

Bob Greenberg’s R/GA Digital Studios created work seen in Superman, Zelig, and Diet Coke commercials.The dancing cars in the Shell Oil ads, the flying dagger in *The Shadow*, and the effects for *The Last Action Hero* were the work of R/GA Digital Studios, the company behind graphics for over 2,000 commercials and 300 feature films.

At its peak, R/GA had 175 employees and grossed $35 million. Restructured in 1992 to resemble a flexible network of nodes, ?R/GA was made up of seven independent companies. Each specialized in one area of visual imagery, from print to interactive entertainment. If a project used more than one medium, the companies turned to each other for help. The result: a one-stop visual-effects house.

1. Text extracted from a Wired Online article, *Real Virtual*, by David Bennahum

R/GREENBERG ASSOCIATES

TELEVISION:
COMMERCIALS & TAGS

- Panasonic Technics Campaign
  Grey
- First Interstate Bank Campaign
  Stimpson Associates
- Texaco
  Benton & Bowles
- Whirlpool Campaign
  D'Arcy MacManus & Masius
- Hershey's
  Doyle Dane Bernbach
- HBO Campaign
  Ted Bates

  Union Carbide/Eveready
  William Esty
- Mobil Magnifications Campaign
  Doyle Dane Bernbach

  General Motors
  N.W. Ayer

  Embassy Telecommunications
  Chermayeff & Geismar
- Sony Beta Hi-Fi
  Backer & Spielvogel
- Gillette
  BBD&O
- IBM
  Doyle Dane Bernbach
- Atari
  Doyle Dane Bernbach
- Newsweek
  Foote Cone & Belding

*INCLUDES
LIVE ACTION









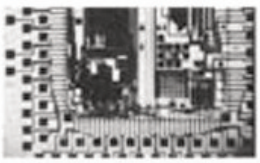













FEATURE FILM:
PROMOTION, TITLES
& VISUAL EFFECTS

The Verdict
20th Century Fox

- The World According to Garp
  Warner Bros.
- Jaws 3-D
  Universal Studios

  Mike's Murder
  The Ladd Company/Warner Bros.

  Gandhi
  Columbia Pictures
- Tootsie
  Columbia Pictures











IN PRODUCTION:

Live action, graphics & special optical effects for: Atari campaign/DDB; Ideal Toys/Towne, Silverstein, Rotter; Timex campaign/Grey; Technics/Grey; Nissan/William Esty; Shell/Ogilvy & Mather; General Electric/BBD&O; MCI/Ally & Gargano; Hallmark/Y&R; Diet Pepsi/BBD&O; Benjamin Moore/Warwick; Pfizer/Doremus; 101 Park Avenue/H.J. Kalkkow; Nothing Lasts Forever titles/MGM/UA; Mike's Murder titles & promotion/The Ladd Company/Warner Bros.; Space Hunter titles & promotion/Columbia Pictures; Greystoke promotion/Warner Bros.; The Big Chill promotion/Columbia Pictures; The Right Stuff promotion/The Ladd Company; Brainstorm promotion/MGM/UA; Ladyhawke promotion/Warner Bros.; Silkwood/ABC Motion Pictures; special visual effects/Woody Allen project

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Ad from 1983 Computer Pictures Magazine

Also in 1992, Bob Greenberg opened RGA/LA to compete with West Coast firms like Industrial Light & Magic. Soon after, R/GA mastered the difficult task of placing a young Clint Eastwood next to President Kennedy for Columbia's *In the Line of Fire*. But it wasn't the first time Greenberg brought the dead and the living together on celluloid – he'd done it before in Woody Allen's *Zelig* and in Diet Coke ads pairing Paula Abdul, Groucho Marx, Gene Kelly and Cary Grant.



R/Greenberg paired Paula Abdul with Cary Grant for this 1992 Coke ad.

Bringing the dead to life was part of R/GA's next big creative push in advertising. Interactive advertising, according to Greenberg, could benefit from taking celebrity endorsement to the next step, where celebrities communicate with customers on an individual basis, creating a personal dialog. Greenberg negotiated with the estates of famous actors for the rights to reanimate them as high-cachet virtual hosts. The first interactive ad, for Chrysler, was released at Time Warner's interactive test site in Orlando, Florida. Another, for the US Postal Service, is scheduled to follow.

Movie 11.11 Superman Opening Sequence

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/Superman-1.m4v

Blue Sky Studios

> "Blue Sky Studios, Inc. was founded in February 1987 by a group of people who had met at MAGI/SynthaVision while they were working on Disney's TRON. Each brought a range of talents and experience that proved valuable in dealing with the emerging business of computer animation. David Brown, the company's current President and CEO, had been a marketing executive with CBS/Fox Video. Alison Brown (no relation), now Vice President of Marketing and Sales,

came from advertising and special effects. The company's creative director, Chris Wedge, was an animation artist and teacher. The most unusual member of the group, and the man responsible for the distinctive look of its films, is Eugene Troubetzkoy, who holds a Ph.D. in theoretical physics from Columbia University. He and former NASA engineer Carl Ludwig developed the proprietary software and renderer that give Blue Sky its competitive edge. "

From *Ray Tracers: Blue Sky Studios* ?By Susan Ohmer, Animation World Magazine?, May 01, 1997

The basic technology used to generate images at MAGI/SynthaVision was "**ray casting**", sometimes inaccurately called ray tracing, which was developed by MAGI engineer Robert Goldstein in the late 60s. Eugene Troubetzskoy was one of the principal software engineers at MAGI, and he reformulated Goldstein's approach for CGI purposes. When Blue Sky was established, Troubetzskoy implemented a similar approach into the Blue Sky software environment, called CGI Studio. This approach to handling the geometry, coupled with the focus on realistic lighting in the software has allowed Blue Sky to create some of the most stunning imagery in the production industry.

Michael Ferraro oversaw the development of the object oriented language and environment, and Chris Wedge, after returning from Ohio State's graduate ACCAD program, provided much of the artistic direction.



Joe's Apartment

Blue Sky produced animation for advertising and television, and ventured into the film production arena with their effects contribution to the David Geffen movie *Joe's Apartment*, based on the MTV short film of the same name. They have also produced effects for *Fight Club* (1999, Fox 2000), *Star Trek: Insurrection* (1998, Paramount); *Alien Resurrection* (1997, 20th Century Fox); *A Simple Wish* (1997, Bubble Factor/Universal Pictures), and *Titan A.E.*

In 1998, Wedge realized a dream in producing a short film entitled *Bunny*, which earned him an Academy Award for Best Animated Short Film. *Bunny* showcased the entire approach to Blue Sky's unique image generation environment, producing incredible lighting environments using radiosity approaches. In 2002 they produced the feature length animated film *Ice Age*, which broke box office records for domestic release.



Scrat (from Ice Age)

In 1999, Twentieth Century Fox bought controlling interest in Blue Sky through their effects division, VIFX who they had purchased earlier, and they merged the two to create Blue Sky/VIFX. Richard Hollander, one of the original founders of VIFX/Video Image, was made President of the new venture, and Blue Sky's former President, David Boyd Brown, took on the position of CEO. The company was headquartered in Marina Del Rey, but Blue Sky's New York facility continued to function. They employed a total of approximately 250 people.

In 1999, VIFX was sold to Rhythm and Hues, and Blue Sky reverted to their previous structure as Blue Sky Studios, still under Fox ownership. David Brown passed away in 2003.

http://blueskystudios.com/our-story/

Movie 11.12 Bunny



Bunny (1988)
https://www.youtube.com/watch?v=Gzv6WAlpENA

Gallery 11.3 Scenes from Bunny



Scene from Bunny

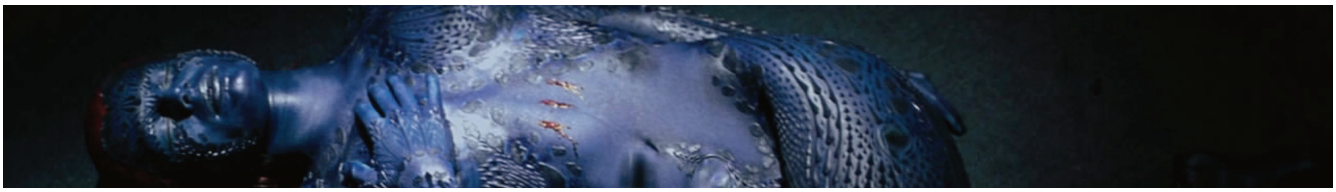


Scene from Bunny



Scene from Bunny

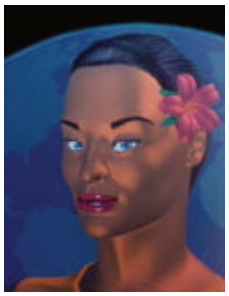
11.8 Kleiser Walczak Construction Company





Kleiser and Walczak

In 1987, Jeff Kleiser (Digital Effects) and Diana Walczak formed Kleiser-Walczak Construction Company in order to build databases as a commercial service. They experimented with CG actors, which they called **Synthespians**. Synthespians were a new brand of animated three-dimensional characters with a high degree of life-like motion. Forged from the imagination of a human sculptor, according to Kleiser-Walczak, "these synthetic actors were brought to life through the process of computer generated imagery (CGI) and human motion capture to create a wholly unique style of animation with vast application to the entertainment industry."



Dozo

Two of the best animations involving Synthespians are *Don't Touch Me*, starring the computer-generated singer Dozo, and *Sextone for President*.



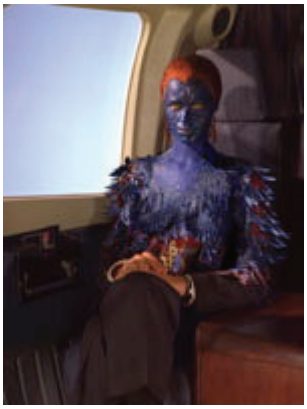
Nestor Sextone

In 1990, the company produced twelve minutes of high-end cosmic simulation for the PBS series *The Astronomers*. This project caught the attention of Doug Trumbull (2001: *A Space Odyssey, Close Encounters, Blade Runner, Silent Running, Brainstorm*), who awarded the company a multimillion dollar contract to set up a facility on-site at the Trumbull Company in Lenox, Massachusetts, to produce films for Luxor Las Vegas. Kleiser-Walczak provided all the computer animation, digitally composted with live action in **Vistavision** at 48 frames per second and a 2 1/2 minute stereoscopic film that was entirely computer-generated.



Scene from Kevin Costner's 500 Nations

In 1992, Kleiser-Walczak teamed up with John Grower's Santa Barbara Studios to simulate four ancient North American cities for the Pathways/Kevin Costner production of *500 Nations*. In 1993, Kleiser and Walczak partnered with Randal Kleiser, who directed Disney's *Honey, I Blew Up the Kids* to produce numerous visual effects shots combining live action and computer animation. They also produced animation for German director Roland Emmerich's *Stargate*, Paramount's *Clear and Present Danger*, Disney's *Honey, I Shrunk the Theater*, *Judge Dredd*, and a stereoscopic logo-opener for IMAX films.



Scene from X-Men

Michael Jackson chose Kleiser-Walczak to design an album cover and video jacket for his anthology album, *HIStory*. For this project, Diana Walczak supervised a four-camera shoot of Jackson and created a highly detailed sculpture of him for digitization and rendering.

In 1997 the company relocated its main facility to the Massachusetts Museum of Contemporary Art in North Adams, Massachusetts where they opened Synthespian Studios, a production facility designed specifically to create computer-generated characters.



Mortal Kombat Annihilation

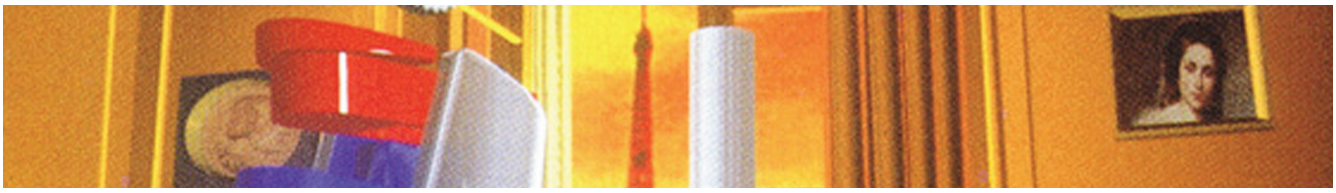
Movie 11.13 Maya Demo
http://www.youtube.com/watch?v=a3KnzIdm7Aw

Movie 11.14 Sextone for President
http://www.youtube.com/watch?v=H9aYZ9KCWPk

Movie 11.15 Don't Touch Me, starring Dozo
http://www.youtube.com/watch?v=8ovn8qRezPA

Movie 11.16 Kevin Costner's *500 Nations*
https://www.youtube.com/watch?v=24IA_viq1ZY

11.9 Sogitec Audiovisuel / Lamb&Company



Sogitec Audiovisuel



Sogitec Logo

Sogitec was very active in the early to mid-80s in CGI production in France. Their productions were innovative, and the image quality was superb. Some of the active participants in Sogitec were Xavier Nicolas, Veronique Damian, and David Salesin, who went to the University of Washington after some time at Lucasfilm and Pixar. Sogitec became a subsidiary of Dassault Aviation in France, and became involved in simulation, but not in CGI directly.



Xavier Nicolas

In 1988, Nicolas formed ExMachina, which proved to be one of the leaders of CGI in Tokyo and Paris. They also worked in location based entertainment and the "Large Screen" entertainment industry, including simulation, 3D and **Imax** formats.

An Animation World Magazine article on Sogitec / ExMachina can be found at ?*https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/05/france-cotte.pdf*

Other French animation companies during this same time period were Thomson Digital Image (later purchased by Wavefront), INA (Institut National de la Communication Audiovisuelle), Voir/Captain Video, Imatique, *Fantome*, and Computer Video Film.

A Computer Graphics World article, *The French Touch in Computer Animation*, was written by Judson Rosebush in 1985.

Movie 11.17 Sogitec



Sogitec Demo reel 1985
https://www.youtube.com/watch?v=S8gMdY9L7Wk

Movie 11.18 ExMachina "Stand By Me"
http://www.youtube.com/watch?v=0MjoqsXkErA

Lamb&Company

Larry Lamb was President of Lamb&Company[1] and the affiliated software company, LambSoft. Lamb founded Lamb&Company in 1980. His contributions to the industry include both early adoption and testing of new software systems and the development of proprietary software code on a large scale. He served on the board of trustees of Minneapolis College of Art & Design (MCAD) and the New Media Advisory Board of the Walker Art Center in Minneapolis.

Lamb operated a continuous but informal 'test lab' for new computer graphics tools since the company was founded. Its history parallels the development of computer animation itself. The first tool adopted by Larry Lamb (he says it was before anyone else) was a servo-controlled **Oxberry animation camera**.

Lamb&Company was well known for its character animation, but they started the company animating flying logos. Lamb&Company acquired the first license of Wavefront software, which allowed Lamb&Company to do production internally without relying on film or outside film support services. The Wavefront *Preview* software complemented the Oxberry equipment by allowing staff to pre-visualize the work being done on the computer controlled animation camera.

In 1987, when one of his competitors went out of business, Lamb bought the core animation technology developed at Cranston/Csuri Productions, one of a handful of 'original' computer animation companies that folded that year. This substantial body of animation software technology served as the basis for Lamb & Company's internal

1. Much of the above text was from the Lamb website at ?http://www.lamb.com

development efforts. Lamb was also an early adopter of Silicon Graphics hardware as the platform of choice for animation, and later added NT machines to its mix.

In 1989, Lamb & Company began to pursue new ways of doing computer animation and began experimenting with motion capture as a means of augmenting keyframe animation. The goal was to develop a computer 'puppet' in order to do high volumes of animation quickly. Two driving needs at the time were the need to produce volume and the need to present personality in the characters. Existing CG looked too 'algorithmic', stiff and computer generated. As part of the exploration of tools to accomplish this, Lamb & Company became the first customer for Virtual Technologies Data data glove. Just having the acquisition device did not constitute an animation solution. It was used as a tool to test motion capture theories as a microcosm system for larger motion capture efforts.

In the early 1990's Lamb bought the Discreet Logic FLAME digital paint and compositing and special visual effects system. In 1992, they also purchased a full body motion capture suit from Ascension Technologies as part of an experimental effort to reduce production costs on a major new animation. It took Lamb & Company six months to create the first long-format computer generated 3D network TV program in the U.S. "*The Incredible Crash Dummies*" (Fox). The need to produce 23 minutes, consisting of 82 scenes with 13 characters on the computer at a time when the computer power was much more limited than today continued the quest for productivity and creativity management tools at Lamb & Company.

The next set of breakthroughs dealt with blending keyframe animation and motion capture data and being able to apply motion data to characters that weren't exactly the same as the performer in shape and size. The company proved the technology during the experimental production "*Huzzah*". This production was the first complete capture of an actor's single performance. In 1997, Lamb & Company spun off LambSoft, a software technology development company whose goal is to productize motion editing and compositing software created as part of the company's long term efforts around blending motion capture with keyframe animation. In 1998, Lamb & Company was featured on "*Scientific American Frontiers*" hosted by Alan Alda.

Movie 11.19 Incredible Crash Dummies

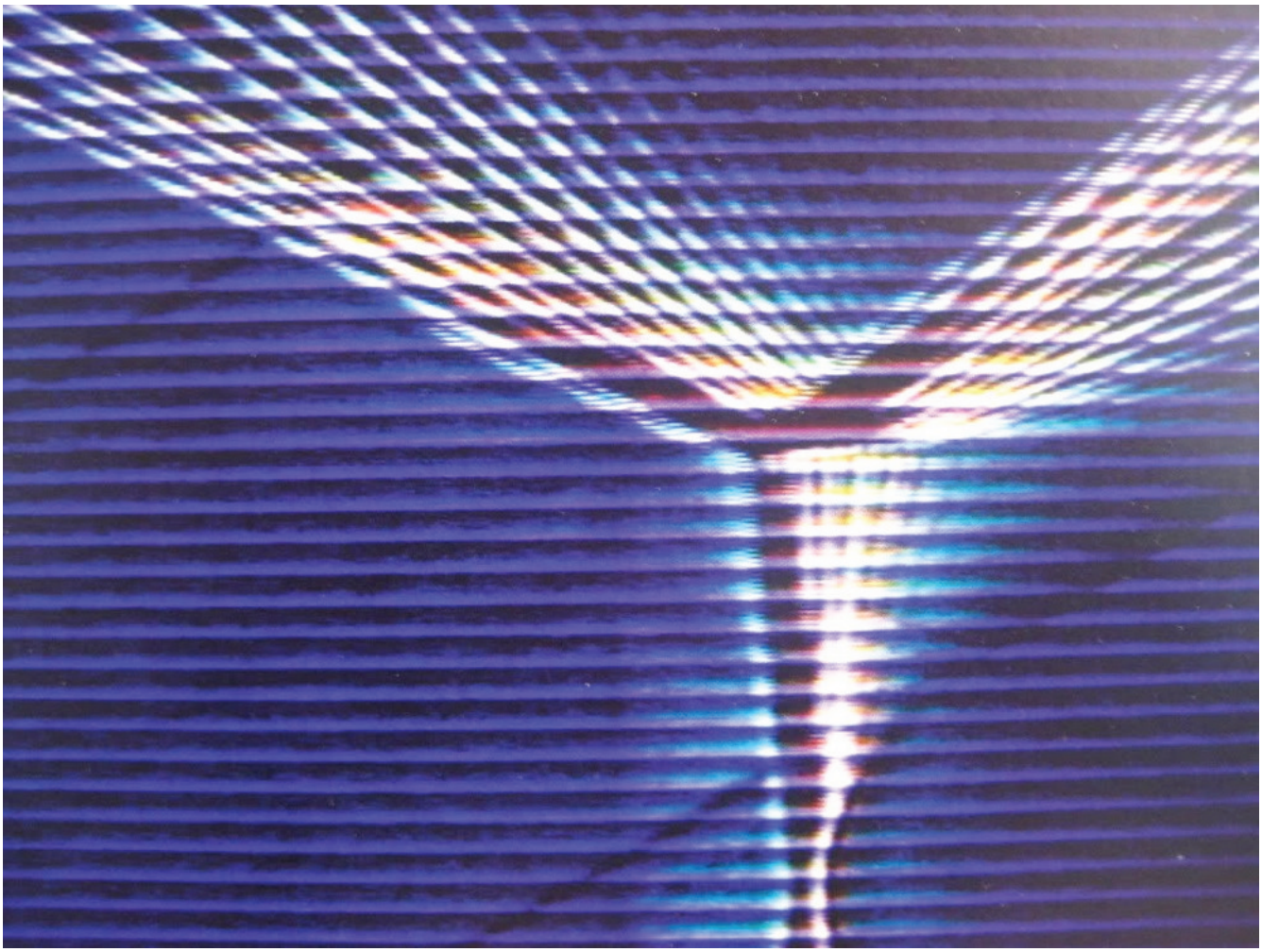


https://www.youtube.com/watch?v=g-WgF5jGVdA

Chapter 12: Analog approaches, non-linear editing, and compositing

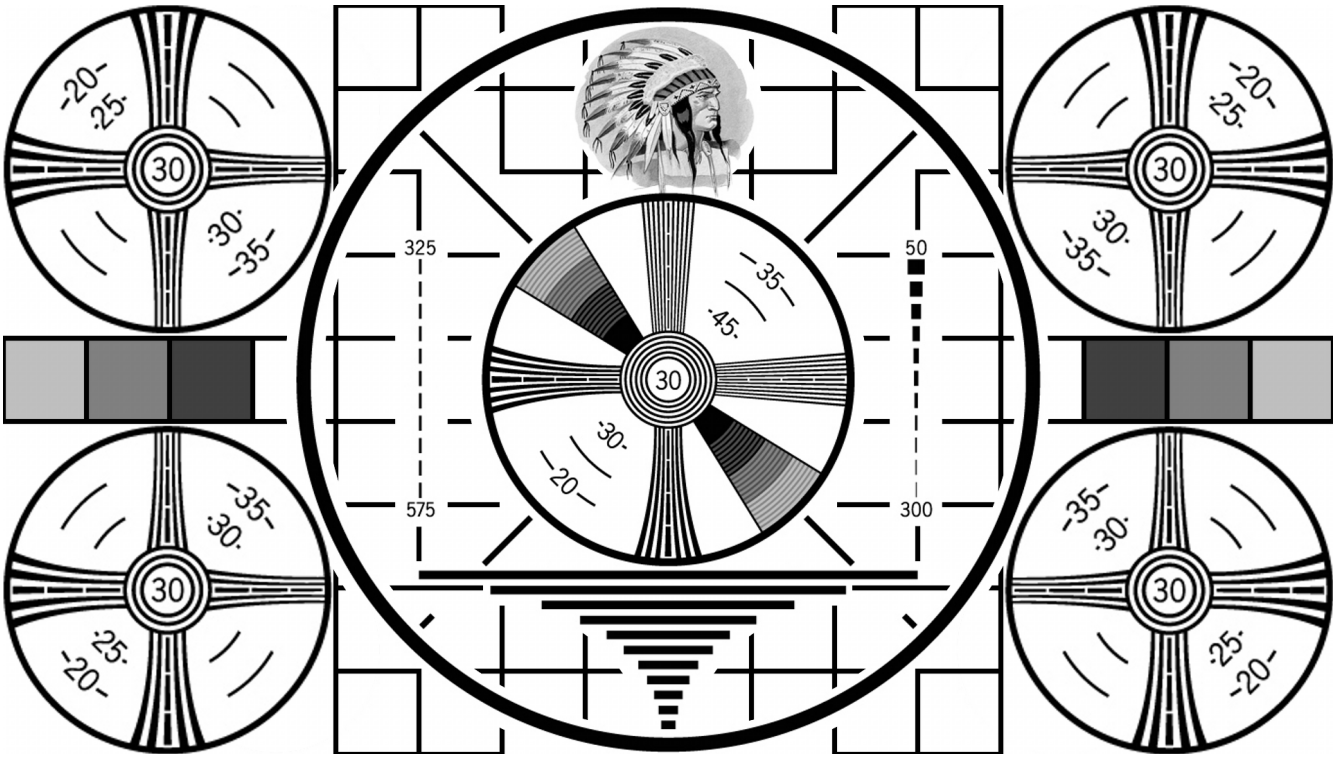
Analog approaches, non-linear editing, and compositing

The development of digital 3D graphics techniques was accompanied by advances in analog approaches. These were typically the real-time manipulation of signals, colorization, movement capture and mapping, and layering or compositing.



Analog generated computer graphics

12.1 Introduction



As seen in the previous section, the 1970s and 1980s saw a proliferation of computer graphics production finding its way into the commercial CG production world. Most of these companies and efforts were built around the evolving digital computer technology, and relied on computer programs and related CG systems to allow the artist to affordably and efficiently create the synthetic imagery. A parallel technology evolution was taking place at the same time, only in the analog world of image-making technology and production. For example, Computer Image Corporation (CIC) developed complex hardware and software systems that included ANIMAC, SCANIMATE and CAESAR. All of these systems worked by scanning in existing artwork, then manipulating it, making it squash, stretch, spin, fly around the screen, colorizing it, scaling or expanding it, etc. Bell Telephone, DuPont, ABC TV, NBC, and CBS Sports were among the many corporations who made use of this style of computer graphics.

12.2 ANIMAC / SCANIMATE



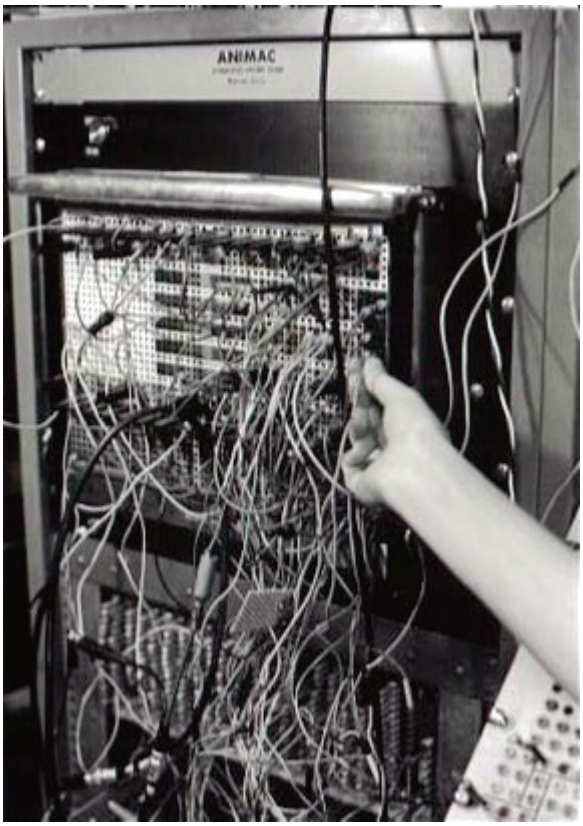


Edwin J. Tajchman (left) & Lee Harrison III receiving the National Academy of Television Arts and Science award for "Outstanding Achievement in Engineering Development"

Perhaps one of the earliest pioneers of this analog computer animation approach was Lee Harrison III. In the early 1960s, he experimented with animating figures using analog circuits and a cathode ray tube. Ahead of his time, he rigged up a body suit with potentiometers and created the first working motion capture rig, animating 3D figures in real-time on his CRT screen. He made several short films with this system, which he called ANIMAC.

Harrison studied at the School of Fine Arts at Washington University in St. Louis. After a stint in the Coast Guard, he joined McDonald Aircraft in St. Louis as a technical illustrator. He returned to Washington University to study engineering, and took a job as an engineer at Philco Corporation in Philadelphia and later as a bio-cybernetic Engineer at the Denver Research Institute at the University of Denver.

It was while he was at Philco that he decided to chase his idea of systematically creating animated figures. His concept was to view a stick figure as a collection of lines that could be independently moved and positioned to form an animated character. Each of the lines would be displayed on a CRT and controlled with a vector deflection of the CRT's electron beam. Each figure would be composed of bones, skin, joints, wrinkles, eyes, and moving lips, all drawn in sequence to create what Harrison called a "cathode ray marionette."



ANIMAC Patch Panels

In order to accomplish this task, he founded a company in Philadelphia called Lee Harrison and Associates. His ideas were realized with a hardware system designed and developed by his new company, which he called called ANIMAC. Harrison participated in the Ars Electronica Festival, along with computer video artists Bill Etra and Bill Diamond and others, in 1992. A facsimile, entitled *Notes for an Early Animation Device* in which the design and operation of ANIMAC was described, is included in the archives of the Festival. The following is from an interview with Jeff Schier, also published in the Festival proceedings:

"WE STARTED OUT by developing what later became ANIMAC. At first we called our machine "The Bone Generator" because it made sections of straight lines that could be hooked together and could be individually animated or moved in three dimensional space. To determine what a bone was you had to determine where it was to start in X, Y, Z space, in which direction it went from there, and for how long, in order to determine its length. The parameters that determined which direction it was going in also determined the actual length projected onto the face of the tube. If you saw a bone from the side you saw its full length but if it were pointing toward you, you saw only a portion of it.

A bone was composed of a bi-stable multi-vibrator or a flip-flop. To start it was to essentially put a signal on a line that governed the opening of a lot of sampling gates. The inputs to the gates were the parameters that governed the position and some of the qualities and characteristics of that bone. To program it we had a patch panel.We always had a navel point on our figures and we'd always flip back to the navel point. We'd go up and out an arm and go back to the navel point, go up and out another arm and back to the navel, go up and out to the head. Those were all fly-back bones and we would fly-back by just collapsing the information that was contained on a capacitor.

In order to determine the length of a bone we used time as the basis. We'd start drawing in a certain direction determined by the specific parameters and we'd go in that direction until we'd turned that bone off and then essentially we'd wait there until we drew another bone. The length was determined by plugging a timing circuit into a place which was reset after each bone. When you started a bone you also started that counter and that flip-flop was plugged into the counter that would turn that bone off. It was pretty much all digital. The next bone would be plugged into another count and so forth and you varied the counts depending. A count represented some number of high frequency units that was part of the clock network of the whole machine.

The patch panel was color-coded and it was a big **patch panel** we got out of the junkyard someplace. If you understood the code you could actually see the bones on this patch panel. There would be a certain color like green and the output might be a blue. If you were going to bone number one, you brought a start pulse that was located somewhere and you'd plug into the first bone and then you'd plug in the output of the first bone into the second bone and so forth. The inputs to the parameter gates were not located on that panel. They were located down a little lower on the face of the Animac

and there were hundreds of them. You had all of these hundreds of inputs required to make the thing happen and to change it over time. After this, the main thrust of our development was to make things change over time which eventually culminated in what we called key frame programming where we would turn knobs until we got what we wanted."



Article in Audio-Visual Communications magazine discusses ANIMAC motion capture

The "skin" was added to the bones by superimposing "springs" that modulated the stick vectors with circular sweeps of spinning vectors. The thickness of the bones, or displacement of the rings from the center of the line, was voltage modulated by a "skin scanner." The scanner was constructed from a "flying spot scanner," a vector camera pointing at an intensity graph with higher brightness representing a larger bone displacement. The "joints" or connection of bones to skin were formed by drawing the bones in a specified order, the endpoints being momentarily held till the next bone was drawn. A synthetic mouth, lips and eyeballs were created through parabolas and sine waves modulated with precise control from voltage sources. The entire figure was manipulated in three dimensions by passing the control signals through a three dimensional (3D) rotation matrix. These control signals were formed from horizontal and vertical sweep generators, with camera angle, size and position voltages run through rotation matrices constructed from adders, multipliers and sine/cosine generators.

To give the illusion of depth, an additional camera tracked the intensity of the skin, giving the illusion of an edge by modulating the skin brightness and leaving it in silhouette. This same camera scanned a texture and superimposed it on the skin surface of the bone.



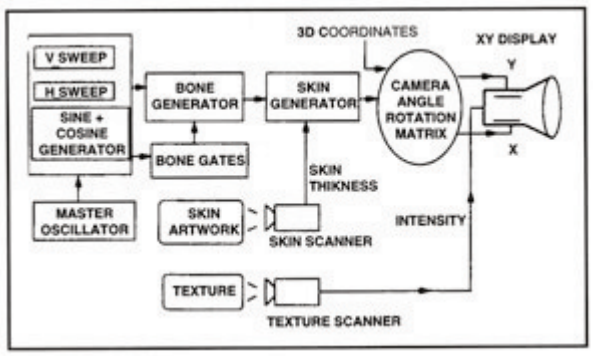
This image composite and the diagram on the next page are from Notes for an Early Animation Device, presented at the Ars Electronica Endo Und Nano Festival, 1992

Harrison's motion capture rigging was a prelude of things to come. The animation harness was fabricated from potentiometers and Lincoln Logs used as armatures. Manipulating the harness tied tactile movement with control voltages, making the character "dance" like the person in the harness.

The ANIMAC was largely a proof of concept prototyped with vacuum tubes mounted on 2 by 4's, using a Heathkit oscillator as the master clock and driving an XY oscilloscope for the display. Harrison's company went public and was renamed Computer Image Corporation in 1969.

That same year ANIMAC was converted into a transistorized version. To commercialize on the scan processing experiments, the approach for moving the

animated character was used instead for moving logos and high contrast graphics about the screen. The skin was "unraveled" and became small movable rasters called "flags." The skin scanner was modified to point at the hi-contrast artwork of a logo or corporate graphic. For example, the intensity of the scanned image filled the undulating flag and was flown and spun across the surface of the screen. The multiple bone mechanism was simplified into five flag generators. The XY display was re-scanned by a video camera with 5 levers of colorization and combined with a background graphic for recording onto video tape. The new machine that incorporated all of these modifications was called Scanimate.



ANIMAC System Diagram

Scanimate allowed interactive control (scaling, rotation, translation), recording and playback of video overlay elements to generate complex 2D animations for television. In fact, most of the 2D flying logos and graphics elements for television advertising and promotion in the 1970s were produced using Scanimate systems.

In 1972 Harrison won an Emmy award for his technical achievements. As computer graphics systems became more powerful in the 1980s, Harrison's analog systems began to be superseded by digital CG rendered keyframe animation, and now are no longer used in production. There are several still running. Dave Sieg brought one to the SIGGRAPH 98 conference as part of a CG history exhibition.



Dave Sieg in front of his working Scanimate at SIGGRAPH 98

Computer Image went on to develop a system called CAESAR, which stood for "Computer Animated Events with Single Axis Rotation." CAESAR was targeted at moving cartoon characters' limbs in an attempt to automate the Saturday morning cartoon production process. CAESAR used most of Scanimate's analog processing technology with digital parameter storage on a Data General minicomputer. According to Dave Sieg:

> CAESAR was never mass produced to my knowledge. A later product, System V was produced, with an improved digital computer, and it replaced Scanimate in several facilities. While at Image West, I also worked on development of a hybrid analog/digital system called VersEFx. But ultimately, the analog image quality produced by such CRT rescan systems could not compete with that of totally digital systems.

Movie 12.1 Scanimate

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/scanimate-1.m4v

This short video shows the operation of the Scanimate analog graphics system

For more about Scanimate, visit Sieg's historical web site at *http://www.scanimate.com*

Dave Sieg wrote an article for the SIGGRAPH newsletter about his experiences with Scanimate as part of the *SIGGRAPH 98 History Project* called *Scanimation in the Analog Days: Notes for an Early Animation Device*

A *final paper* on ANIMAC was presented by Lee Harrison at the *Ars Electronica Endo Und Nano Festival,* in 1992

E.J. Tajchman, *The Incredible Electronic Animation Machine: A Computer System Called CAESAR Is Conquering New World for Video Graphics*, Videographics Magazine, Nov 1977, pp 22-24.

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/03/IncredibleElectronic.pdf

Birger Anderson, *Case Study: A Look at Video Animation*, Broadcast Engineering, May 1979.

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/03/article.pdf

Jeff Schier wrote in an essay for Ars Electronica in 1996 [1] of a visit to and conversation with Lee Harrison:

> In my search for the oldest [films] I could find, I stumbled over the film of the ANIMAC, the first and the only machine of its name. "And where is the machine?" we asked eagerly. "On the dump" came the reply!
>
> Once more we realized how hostile the industrial environment could be to a unique machine like this. How many fabulous designs are being destroyed daily just for a few cubic feet of space or the vanity of an engineer promoting his new brood. Of course Lee knew that. "They finally talked me into it!" he said sadly.

Movie 12.2 Scanimate – a conversation with Roy Weinstock



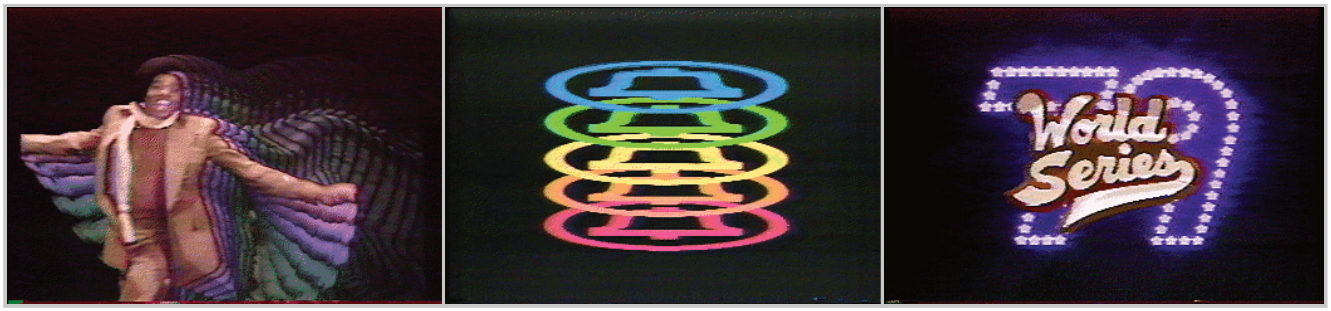
http://www.youtube.com/watch?v=n9CQddf-Bdw

1. *http://90.146.8.18/en/archives/festival_archive/festival_catalogs/festival_artikel.asp?iProjectID=9526*

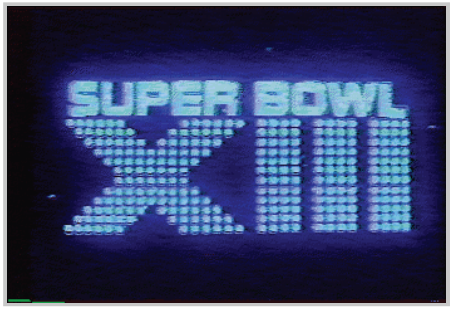
Gallery 12.1 Images from SCANIMATE



Graphics produced on Scanimate KCOP-TV

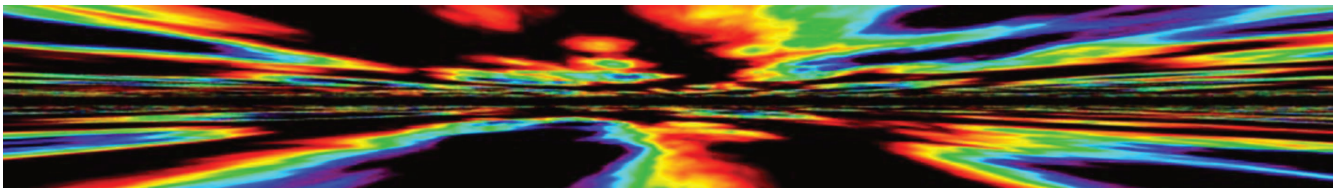


Bell Telephone 79 World Series



Superbowl Graphics

12.3 Image West / Dolphin Productions / Ron Hays



During the late 1970s and early 1980s, several analog video production companies were contributing animation to television networks and stations and advertising agencies. Some added animation to post-production capabilities, and some rose out of the increased demand for "innovative" graphics. Among the companies were Editel, Klein&, and the Post Group. Three pioneering prominent companies were Computer Image in Denver, Image West in Hollywood, and Dolphin in New York.

Image West



Image West Logo

According to Dave Sieg, in a special article written for the Siggraph 98 conference history project [1]:

> In 1977, Computer Image decided it could find a larger market by having a facility in Hollywood, so it borrowed heavily and set up a new company, Image West, Ltd. The company, while very good technically, did not know the Hollywood market well, and was eventually foreclosed by its bank. The bank then approached Computer Image's largest customer, Omnibus, Inc. from Canada and offered to have them take over Image West. Omnibus agreed, and operated the company until 1982 when it sold Image West and went on to form Omnibus Computer Graphics Inc., using digital technology licensed from the New York Institute of Technology. Image West continued to operate SCANIMATES until 1986 when it discontinued operations.

Cliff Brown was president and David Sieg was Chief Engineer at Image West. Several other technologies were investigated during this period. At Image West, Seig engineered the VersEFX, a system in which full-color transparencies could be used as input. According to Sieg, "Digital oscillators and 3D perspective were incorporated to animate the same video parameters found in Scanimate." The first system was shipped overseas, and Image West began building a second. At the same time, at Computer Image Corp., Ed Tajchman created the System IV, a digital 3D animation system. Its input was still monochrome video, and it was quite expensive. The

1. Sieg, Dave. Scanimation in the Analog Days. SIGGRAPH 98 History Project. *http://www.siggraph.org/publications/newsletter/v32n3/contributions/sieg.html*

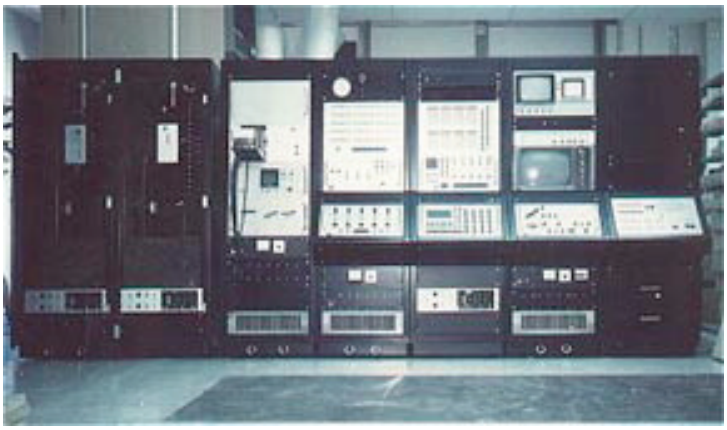
System IV was briefly used in production [2], but fell victim to the rise of turnkey digital animation solutions, such as the Ampex Digital Optics (ADO), digital paint systems such as the Quantel Paint Box, and 3D animation systems such as the Bosch FGS-4000 that were much less costly. This technology change impacted the company's bottom line and they responded by buying a new Symbolics system with both paint and 3D capabilities, but as with a number of similar production facilities, the innovation caught up with them and they went out of business. They tried a last ditch effort to go public, but failed.

Dolphin Productions



Dolphin Productions Logo

Of the first eight SCANIMATES built by Harrison, six were in the United States. Two were in Denver at his company, Computer Image Corporation. Two Scanimates were in New York at Dolphin Productions (a division of Computer Image), two more were in Hollywood at Image West, and two were overseas in Japan. Dolphin Productions worked closely with PBS's Sesame Street and The Electric Company. Allen Stanley was the President at Dolphin.



The Scanimate installed at Dolphin Productions in 1974

2. Ed Kramer maintains a YouTube channel that contains a number of sample demo clips and discussions of production process, called The Basement Tapes, that can be seen at *https://m.youtube.com/channel/UCa2OzKEXQfIqAHlXOjJ8seA*

Ron Hays Music Image



Ron Hays Logo

The New Television Workshop at WGBH supported the creation and broadcast of experimental works by artists. One of their projects was the Music Image Workshop, which was primarily a project of Ron Hays, who used the Paik-Abe **videosynthesizer** to create elaborate visual scores set to music. It was funded by the Rockefeller Foundation and the National Endowment for the Arts from 1972 through 1974. Hays worked closely with WGBH producer and director, David Atwood, to create both live broadcasts and finished works. Additionally, works by other artists were presented under the auspices of the Music Image Workshop.

Hays later produced a short film with Michael Tilson Thomas, called Space for Head and Hands. It was an improvisation by Hays with piano by Thomas. He also produced animation for the Julie Christie movie *Demon Seed*, and a video art compilation of music, computer graphics and art for Odyssey called Ron Hays Music Image. This animation was produced using the Scanimate system.

Movie 12.3 Image West



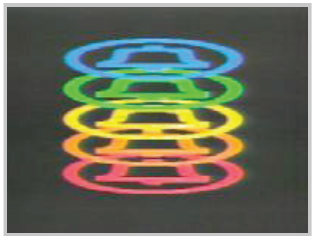
Graphics from the 1981 Image West commercial demo reel
https://www.youtube.com/watch?v=ispW6-7b2sA

Movie 12.4 Ron Hays Music Image Demo



http://www.youtube.com/watch?v=kACpN3vhFtY

Gallery 12.2 Image West Collection



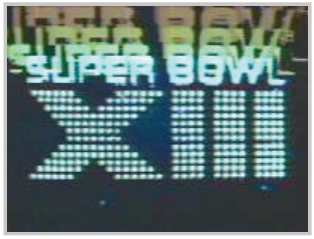


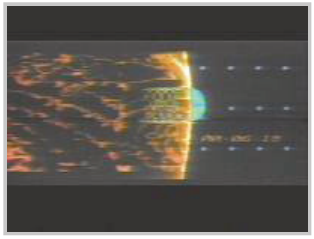


Graphics produced on Scanimate at Image West











Gallery 12.3 Dolphin Studios Collection



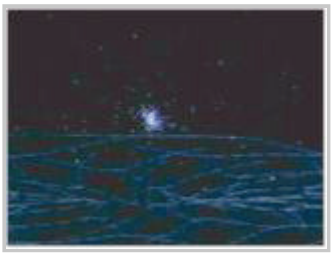




Graphics produced on Scanimate at Dolphin

Gallery 12.4 Ron Hays Music Image Collection





Graphics produced by Ron Hays





12.4 Quantel



Quantel was founded by Peter Michael in 1973 in Newbury, UK. It's focus was to create technology for use in television production. Its first product was the DFS 3000, which was the first digital frame-store. The DFS 3000 is most widely known as the device that allowed the first inset video for television broadcast, a video image inset into the main picture showing a close-up of the Olympic torch integrated with video inside the stadium at the 1976 Montreal Olympics. They followed this with a series of digital effects devices, including the DPE 5000 and the DLS 6000.

Movie 12.5 Quantel – PIP

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/olympic-pip-flame-1.m4v

The Olympic flame was integrated into a video of the stadium in a Quantel box, as the first Picture-In-Picture

The most widely known Quantel product was the Paintbox, introduced in 1981 and still in production at facilities all over the world. The Paintbox was considered one of the first commercial paint systems, and was actually introduced at the spring NAB show in 1980. Quantel obtained patents related to the system, and challenged the entire digital image community with a series of controversial infringement lawsuits. (See the sidebar for more information about these proceedings.) The Paintbox spawned a range of digital technologies from Quantel.

The next device was released in 1982, Called the Mirage, it was the first digital effects machine able to manipulate 3D images in 3D space. It also used an interesting method for transforming one image into another by using a two-dimensional "particle system" to map pixels from one image onto pixels from the second image. As the pixel tiles moved over time, the first image appears to disintegrate and then restructure itself into the second image.

Another radical leap was made in 1986 when Quantel introduced Harry, the world's first non-linear editor. NLEs became fairly standard in the editing business, making linear editing suites largely obsolete. In some ways Harry did for video editors what Paintbox had done for graphic designers, giving them a tool for moving their trade forward by leaps and bounds. The Harry combined several minutes of digital-disk storage with a 2D graphics system and a crude but elegant means to assemble video clips. It was the only digital non-linear editing workstation capable of producing broadcast-quality material for almost a decade.

Other important Quantel contributions can be seen below from their timeline at *http://www.quantel.com*

- 1975: DFS 3000 The world's first digital framestore.
- 1977: DSC 4002 The first portable digital standards converter.
- 1978: DPE 5000 The first commercially successful digital effects machine.
- 1980: DLS 6000 Digital still storage for on-air presentation.
- 1981: Paintbox The industry standard graphics kit.
- 1982: Mirage The first digital effects machine able to manipulate 3D images in 3D space.
- 1986: Harry The first NLE also makes multilayering of live video a practical proposition.
- 1989: V-series The second generation Paintbox. Faster, smaller and more powerful
- 1990: Picturebox Integrates the storage, presentation and management of stills.
- 1990: Harriet Manipulating live graphics over video.
- 1992: Henry The effects editor. Offers simultaneous layering of multiple live video sources.
- 1992: Hal The video design suite. The first dedicated graphics and compositing centre.



Max Headroom

Note: The Paintbox was used extensively in producing the graphics for the 1985 British television series Max Headroom.

There were several other video image manipulation technologies that competed with the Harry. For example, in 1981 Ampex introduced the ADO® system, which created digital special effects, allowing rotation and perspective of video images.

The earliest digital compositing suites for video were Quantel's dedicated hardware systems, like the Harry. Quantel's Domino console first evolved the power to take digital compositing to film resolutions. Many post houses used Quantel systems for their ability to process large dataflows in real time (something that later, open systems running on PCs and offering the flexibility of multiple software use were often less able to provide).

Flame, developed by Australian Garry Tregaskis was the first software-only system to run on the Silicon Graphics platform as the general computing power needed to process layers of video and effects became available. Part of the appeal was that these were hardware units which could also be devoted to other tasks, such as editing and 3D graphics.

A plethora of software products running on Unix and NT systems followed. Some evolved from the proprietary software of production studios like ILM or Digital Domain, or NYPD in Australia, in the case of Digital Fusion. Others were developed from the ground up as commercial products by the creators of non-linear editing, 3D or other graphics systems. Adobe's After Effects, one of the least expensive desktop video compositors, is still basically an adaption of Photoshop with keyframe animation.

Movie 12.6 Max Headroom

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/headroom-1.m4v

Max Headroom: 20 Minutes into the Future is a 1985 cyberpunk television movie created by Chrysalis Visual Programming Ltd. for Channel 4 in the UK to provide a back story for Max Headroom, a computer generated TV host. The series also ran in the U.S. from 1987-1988.

Dick Phillips wrote about the Quantel lawsuits in a 1998 SIGGRAPH newsletter. The following is an excerpt from the article, which can be read in its entirety at

http://www.siggraph.org/publications/newsletter/v32n3/contributions/phillips.html

In fact, it was as recent as 1996 that digital paint systems became the subject of a lawsuit. This is surprising, especially when you consider that [Smith97] points out that the first digital paint program can be traced back to 1969. But it was indeed in January 1996 that Adobe Systems Inc. was sued by Quantel Ltd. for alleged infringement of five of their patents by Adobe's Photoshop product. The stakes were huge; Quantel was seeking damages of $138 million, to be trebled if willful infringement was determined. Moreover, Quantel was seeking an injunction to stop Adobe from selling Photoshop.

Chapter 13: Flight Simulation

Flight Simulation

Rolfe and Staples, in their 1986 book *Flight Simulation*, note that “the object of flight simulation is to reproduce on the ground the behavior of an aircraft in flight.” Much of this reproduction had to do with believable visual synthesis that mimicked reality.



Scene from Microsoft Flight Simulator

13.1 Phase I-III





The physical simulator had a mock-up of the cockpit mounted on computer controllable pneumatic devices to simulate motion. The visual component of the simulator generated images that were presented to the training pilot on display devices mounted inside the physical simulator

Rolfe and Staples, in their 1986 book *Flight Simulation*, note that “the object of flight simulation is to reproduce on the ground the behavior of an aircraft in flight.” This includes the use of physical simulators, with the real and perceived motion that satisfy the motion cues expected by the human pilot, as well as the extremely important visual system, which includes the generation and display of a simulated perspective view of the outside world. These two are inextricably linked, as the visual response can trigger perceptions in the physical reaction, and vice versa. In 1986 there were over 500 simulators in use. We will review a few that have had an impact on the field of computer graphics and animation.

The early visual systems, dating from the late 1950s or early 1960s, included film systems and closed circuit television systems. The film system used a 35mm or 70 mm film that was shot from a real airplane. Servo driven optics distorted the image to simulate a range of other flight paths responding to pilot interaction. The CCTV system moved a camera with a special optical lens over a physical terrain model, or terrain board. Neither approach was very practical, even though high degrees of realism could be achieved, because variations were not easy to present, and situations that may confront a pilot in flight were limited. These early systems were replaced in the early 1970s with CGI systems, or CIG (Computer Image Generators) as they were often called.



CCTV Terrain Board

The first computer image generation systems for simulation (Phase I) were produced by the General Electric Company (USA) for the space program. Early versions of these systems produced a patterned “ground plane” image, while later systems were able to generate images of three-dimensional objects.



The visual component of the simulator generated images that were presented to the training pilot on display devices mounted inside the physical simulator.

Night-only systems usually used vector devices, rather than the raster scan display that gives the image complexity used today. The first of these systems was produced by the McDonnell-Douglas Electronics Corporation in 1971 and was called Vital II (Virtual Image Takeoff And Landing). It was certified by the FAA for commercial flight training for Pacific Southwest Airlines in 1972. The scene was only a night scene of an airport, showing the light pattern of the runways. As an FAA commercial Phase II system, it had to be capable of showing directional lights (only visible from certain directions), flashing lights or beacons, runway end illuminator lights, and vertical approach slope indicators, which are white when the correct approach slope is maintained, and red otherwise.



Daytime simulation



Nighttime simulation

Phase III systems, on the other hand, were required to show day scenes of greater detail. The airport had to be recognizable, and terrain and physical landmarks had to be visible. In order to adequately represent these complex visual images, raster systems were employed.

Military simulation systems require significantly more complexity than the "takeoff/landing" visual simulations for commercial simulators. They require the simulation of complicated maneuvers, perhaps carrier landing, high speed flight, ground attack situations, etc. The vector devices used for many commercial systems were not sufficient, and the industry embarked on serious research and development efforts that both contributed to and took advantage of parallel efforts in CGI for special effects activities for movies, etc.

A Brief History of Aircraft Flight Simulation
Kevin Moore

J.M. Rolfe and K.J. Staples, Flight Simulation, Cambridge University Press, London, 1986

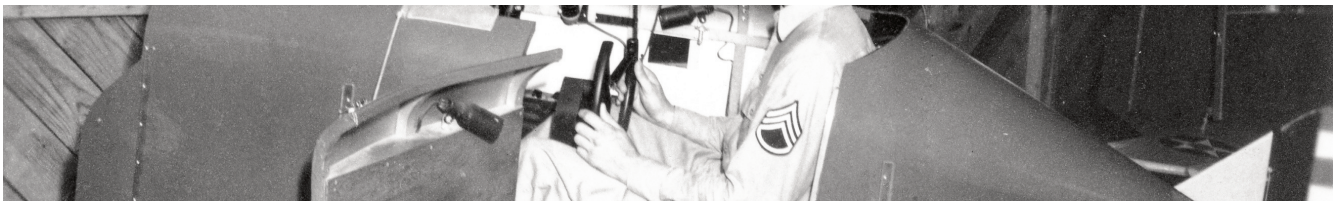
A Brief Introduction to the Art of Flight Simulation Ron Reisman
E1990b_159

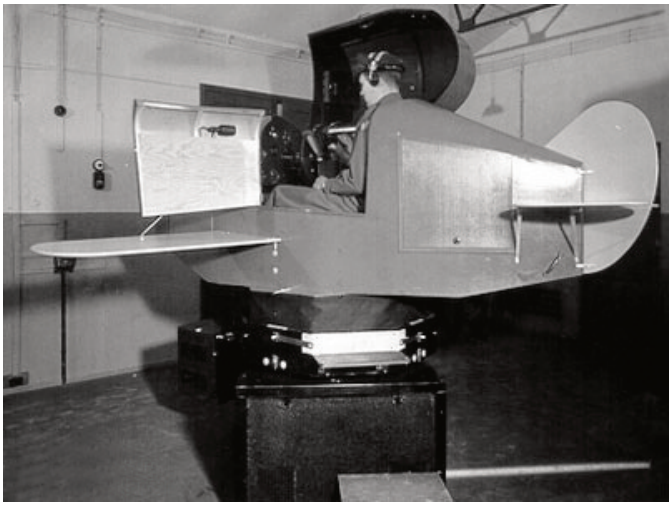
"Computers in Spaceflight: The NASA Experience"
http://www.hq.nasa.gov/pao/History/computers/Ch9-2.html

Movie 13.1 Flight Simulation

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/flightsim-1.m4v

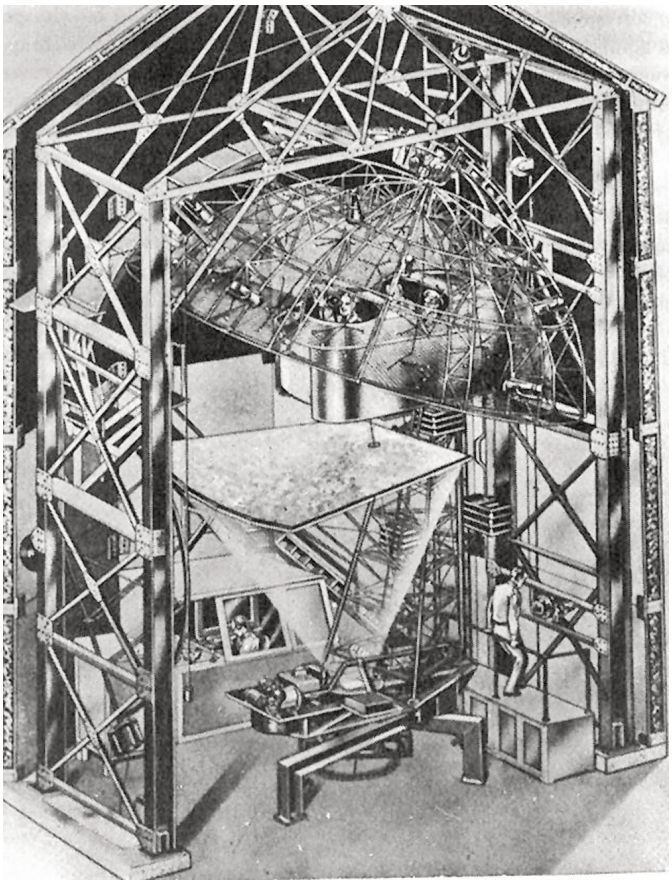
13.2 Singer Link





The Link Trainer provided primarily instrument training.

The Link Company was one of the first companies to develop flight simulators. Edwin Link worked for his father in a piano and organ company in New York, and designed his first “Link trainer”, the Link “Blue Box”, in his basement between 1927 and 1929. The U.S. Army Air Corps recognized the value of the trainer and they pushed the development of Link’s original idea to include more sophisticated control and monitoring devices. It was very successful during the 1930s and into World War II, even used by German pilots as well as U.S. and British pilots. Initially there was no visual feedback. The trainer was used primarily to familiarize the pilot with instruments, and to give some rudimentary motion feedback to control stick manipulation. A first form of visual feedback for a later Link Trainer was a cyclorama. The scene from the cockpit was painted on the walls of the training room.



The Link Celestial Navigation Trainer is shown here. The pilot and co-pilot can be seen in the fuselage at the top center. Below the fuselage was a screen on which was projected a moving image of terrain. Above was the dome with lights representing stars and constellations of the appropriate hemisphere, and the dome moved on the overhead track to represent the passage of time. Smoke was used to simulate cloud or fog, etc. The device was housed in an air conditioned octagonal silo that was approximately 45 feet high. Click to see a larger version.

In 1939, Link developed a trainer that allowed for cross Atlantic navigation and night training, called the "celestial navigation trainer." It represented stars on a dome over the physical trainer, and the stars could be relocated to correspond with time as well as changes in location.

With the desire for better motion control of the trainer came the development of analog and later digital control mechanisms. In the early 1960s, Link developed the Link Mark I computer to accomplish real time simulation by computing aircraft equations of motion.

Link merged with the General Precision Equipment Corporation in 1954, and in 1968 was purchased by the Singer Company, of sewing machine fame. In 1981, the same year as Ed Link died, the Link division split into the Link Simulation Systems Division (Maryland) and the Link Flight Simulation Division (California). In 1988 CAE Industries from Canada purchased the Maryland operation, and consolidated it with the Flight Simulation Division in 1990, to form CAE-Link Corporation.



The Link Celestial Navigation System?. You can see the "cockpit" with the navigator and pilot trainees shown above. They were situated right under the projection dome.

In the 1960s, the General Precision Group of Singer-Link began working with NASA to develop simulators for the Gemini space program. Singer held the contract for the simulators under the direction of prime contractor McDonnell-Douglas, which supplied cabin and instrumentation mock-ups. Fully functional simulators came on line at Cape Canaveral and Houston in 1964.

In 1978, the Singer-Link DIG or "Digital Image Generator" was developed. This device is considered to be one of the world's first-generation Computer-Generated-Image (CGI) systems.??In the 1980s, during the height of the Cold War, Singer-Link fielded simulators for numerous military systems, including the B52-G, AH-64 Apache, B-1B, F-16C, P3-C Orion, and S3-B Viking aircraft. Singer-Link also developed a number of ship and submarine trainers for ASW (Anti-Submarine Warfare), Mine Warfare, and Sonar System Training. In the 1990s, Singer developed commercial flight simulators such as the MD88. Singer-Link simulators and the DIG Digital Image Generator were featured in the 1987 NOVA Season 14, Episode 3 show called *Why Planes Crash*.



The Link Celestial Navigation System towers in front of hanger at McCook Army Airfield in Nebraska

Ed Link's breakthrough in demonstrating his pilot trainer finally came when the government contracted with the Army Air Corps to start carrying the U.S. mail. This experiment unfortunately would soon meet with disaster, primarily because Army Air Corps pilots had been trained to fly by watching the ground.

During their first week of mail service Army Air Corps pilots experienced extremely hazardous weather. Tragically, nearly a dozen pilots were killed due to the bad weather they encountered. This tragedy prompted the Army Air Corps to take a closer look at Link's invention that trained pilots to fly by instruments.

On a foggy, misty day in 1934, a group of Army officers awaited Ed's arrival in Newark, New Jersey. Ed was flying in from Binghamton, New York.

The officers, convinced that he couldn't make it in such soupy weather, were about to leave. Just as they were about to leave they could hear the sound of an approaching airplane. Within a minute's time an aircraft circled the field and touched down on the runway. It was Ed Link…he had flown in on instruments and demonstrated that effective flight was possible even during adverse weather conditions.

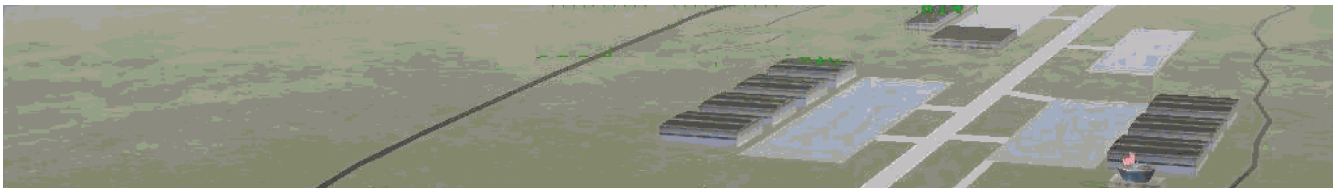
From the Link website at *http://www.link.com/history.html*

Movie 13.2 Singer-Link



Singer-Link DIG flight simulator visual image demonstration video
https://www.youtube.com/watch?v=uy8sJ9AxvYI

13.3 Evans and Sutherland





E&S Founders

E&S Logo

Evans & Sutherland, with its connection to the University of Utah, attracted a large number of the leading CG researchers of the late 1960s and 1970s. They developed algorithmic approaches to high performance image making, as well as the hardware workstations that could support the software. They developed the LDS-1 and LDS-2, followed by a line of graphics workstations, called the E&S Picture System. These were used by most of the CGI production companies through the 1980s. They also developed the CT-5 and CT-6 flight simulators. After many years of successful marketing , they changed the acronym of their simulation products from CT (Continuous Texture) to ESIG (Evans & Sutherland Image Generator) for their simulation product line.



December 1969:
Ivan Sutherland(left) and Dave Evans(right) with LDS1.

LDS-1

E&S developed turnkey simulation systems for military and commercial training,?including systems for air, sea, and land simulation. Their expertise in this area also opened a market for digital theater products, such as planetarium theater systems, domed theater presentations, and digital projection systems. The visualization industry also was partial to E&S products, and they also developed graphics acceleration products for professional workstations and personal computers.



Workers in E&S space at University of Utah.

E&S holds many CG related patents. In the late 1980s, they threatened a number of workstation manufacturers with patent infringement for a number of technologies, most notably clipping.

The following was excerpted from the E&S history page. (A more recent history can be found on their current website at ?*http://www.es.com/About/History.html*)

> “For more than 30 years, Evans & Sutherland has been the power behind the scenes, providing complete visualization solutions for a wide variety of applications. Whether it’s for training simulation, education, entertainment, or business, E&S creates the technology that makes it come alive.

It was 1968 when Professor David Evans, founder of the University of Utah's computer science department, convinced his friend and associate, Dr. Ivan Sutherland, to leave his teaching position at Harvard and join him in a new venture in Utah. That year, the two professors began a collaboration that would shape the history of the computer industry. Their collaboration, based on their theory that computers could be used interactively for a variety of tasks, became Evans & Sutherland Computer Corporation. Established in abandoned barracks on the campus of the University of Utah, the company began by recruiting students from the university and looking for new ways to use computers as tools.



E&S scientist at the controls of one of the company's display devices.

Although E&S is hailed as a leader in computer graphics technology, David Evans contended that developing graphics was only part of the dream. In starting the company, he had a different idea: that computers were simulators. Simulators can replace real objects on occasions when a simulation can be built more cheaply than the physical model can be. "The company began with graphics because we thought they were an essential link between the human user and the simulation."



Scene from the E&S Flight Simulator

The strongly academic environment surrounding E&S provided a uniquely creative and academic work environment that shaped and refined some of the most innovative minds in computer graphics. Many of today's computer graphics visionaries began their careers at Evans & Sutherland. Industry leaders such as Jim Clark, who started Silicon Graphics, Ed Catmull, founder of Pixar Animation Studios, and John Warnock, president and founder of Adobe, trace their roots back to Utah and E&S and the tutelage of Dave Evans and Ivan Sutherland.



Scene from the E&S Flight Simulator

With its emphasis on computers as simulators, training became a natural market for E&S, so the company continued to develop and enhance its simulation systems. Then, in the mid-1970's, E&S established a partnership with Rediffusion, a British simulation company, that gave E&S exclusive rights to provide visual systems for

Rediffusion's commercial flight training simulators. At one point approximately 80% of the world's commercial airline pilots were trained on simulators using E&S visual systems.

Like the computer graphics industry as a whole, E&S saw significant growth and enormous change during its first 15 years. The company stayed on the leading edge of computer graphics technology as it broadened its product line of visual systems for simulation. And, using the technologies developed for simulation, E&S began exploring some new applications such as planetarium systems.

During that time, the company outgrew the barracks on the University of Utah campus, and E&S became one of the first residents of the university's new research park. Employment continued to grow as the company's business base grew. Then, in 1975, Ivan Sutherland left E&S to pursue other interests. He became a research fellow at Sun Microsystems, but he stayed on as a member of the E&S Board of Directors. 1978 marked another milestone for E&S when the company went public.



Scene from E&S Simulation system

In the 1980's, a worldwide recession and changing marketplace brought serious challenges to the company. But E&S continued to lead the simulation industry in providing the highest quality, most realistic visual systems in the world as it looked for new markets for its technology, such as digital projectors for planetariums and entertainment applications.

The early 1990's were a period of change for the company as Dr. Evans retired. In 1994, James Oyler joined E&S as President and CEO. Under Mr. Oyler's leadership, the company continued to lead the visual systems industry for both military and commercial simulation applications as it leveraged its technologies into entertainment, education and workstation applications.

The company's businesses expanded to include visual systems for all kinds of military and commercial training, including systems for air, sea, and land simulation; digital theater products, such as planetarium theater systems, domed theater presentations, and digital projection systems; virtual set products for video and television

producers; visualization products for land developers; and **graphics acceleration** products for professional workstations.

Evans and Sutherland list of patents[1]
http://patents.justia.com/assignee/evans-sutherland-computer-corporation
and
http://patents.justia.com/assignee/evans-sutherland-computer-corp

"Computers in Spaceflight: The NASA Experience"
http://www.hq.nasa.gov/pao/History/computers/Ch9-2.html

E&S Tactical Edge (1980)
http://www.youtube.com/watch?v=06mbwNg1Vw4

E&S CT5 (1981)
http://www.youtube.com/watch?v=6W-qb_jHRhA

Movie 13.3 E&S History

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/e-s-history-1.m4v

This video takes you through the history of the Evans and Sutherland Computer Company from its founding at the University of Utah

Gallery 13.1 Scenes from E&S Simulators



Realistic scenes from the E&S Flight Simulator



Fuel tanker



Attack helicopter

1. After threatening several companies with legal action regarding patent infringement in the area of 3D graphics, E&S did a turnaround in 2001 and licensed its patents (it held around 79 such patents) to Nvidia. As PCWorld reported in October of that year, "Graphics chip supplier Nvidia Corp. here today announced a broad alliance with Evans & Sutherland Computer Corp., which has agreed to sell key patents for three-dimensional graphics technologies to Nvidia. Also under the alliance, the two companies said they would cross-license technologies to each other, and Nvidia has agreed to license its Shader Technology to E&S of Salt Lake City, which is a pioneer in 3D graphics."



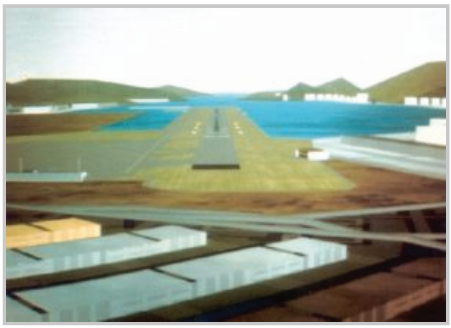
Realistic ground scene



Cockpit



Planetarium simulation



Daylight Scene



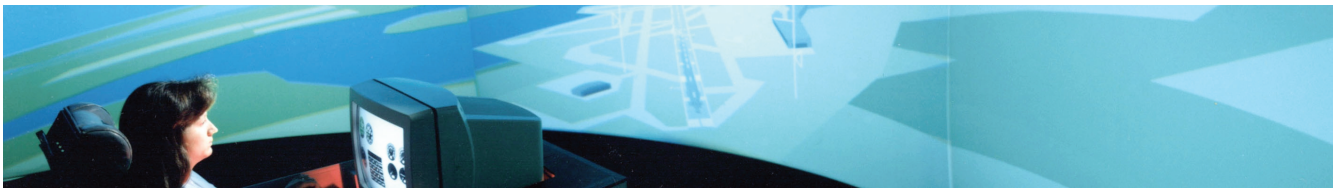
Night Scene



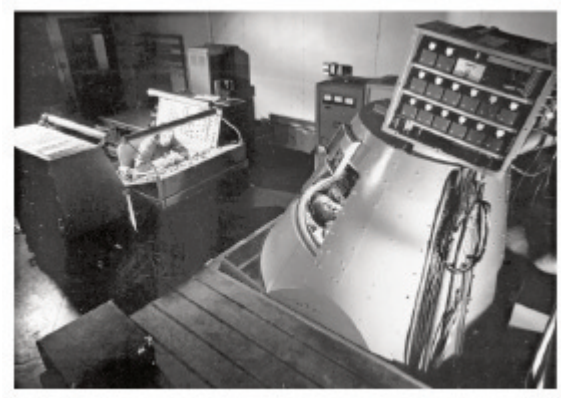
Dusk Scene



13.4 NASA

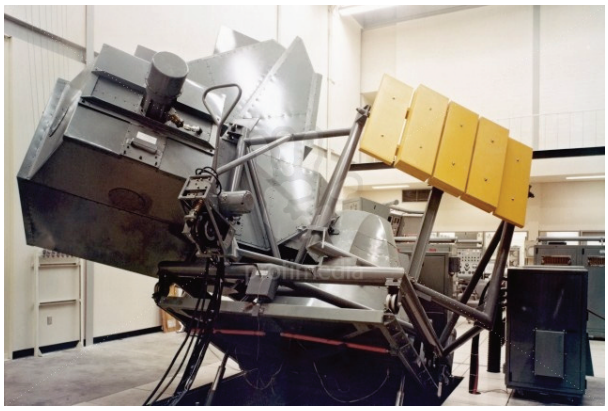


NASA's requirements for flight simulators far exceeded the state of the art when the first astronaut crews reported for duty in 1959. Feeling obligated to prepare the astronauts for every possible contingency, NASA required hundreds of training hours in high fidelity simulators. Each crewman in the Mercury, Gemini, and Apollo programs spent one third or more of his total training time in simulators.



John Glenn, one of the Mercury Seven Astronauts, runs through a training exercise in the Mercury Procedures (Link) Trainer at the Space Task Group, Langley Field, Virginia

The primary simulator for the first manned spacecraft was the Mercury Procedures Simulator (MPS), of which two existed. One was at Langley Space Flight Center, and the other at the Mission Control Center at Cape Canaveral. Analog computers calculated the equations of motion for these simulators, providing signals for the cockpit displays.



Gemini Mission Simulator

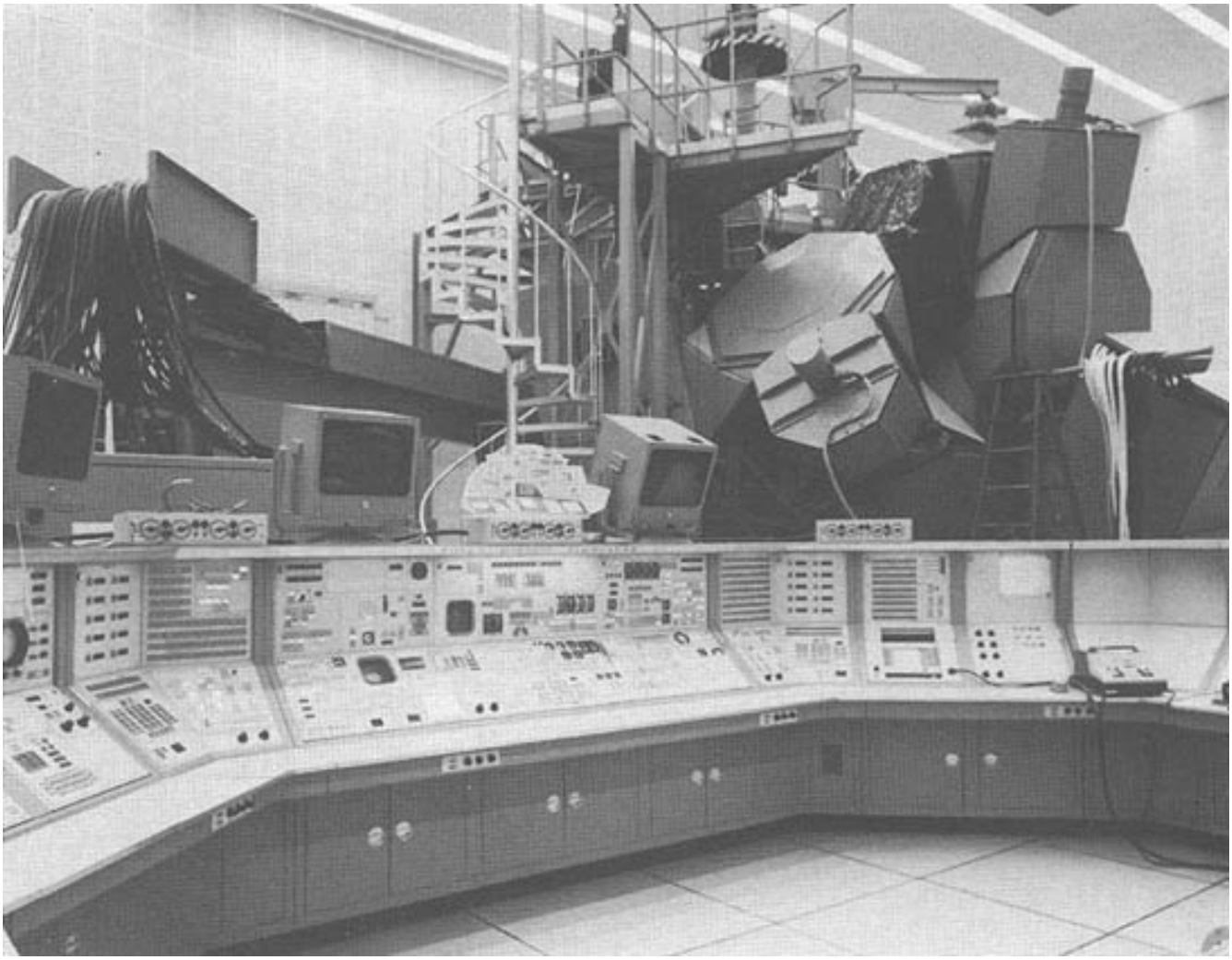
The Gemini Mission Simulators used between 1963 and 1966 in the space program operated on a mix of analog and digital data and thus were a transition between the nearly all-analog Mercury equipment and the nearly all-digital Apollo and later equipment. Three DDP-224 digital computers performed the data processing tasks in the Mission Simulator. Built by Computer Control Corporation, which was later absorbed by Honeywell Corporation in 1966, the three computers provided the simulator with

display signals, a functional simulation of the activities of the onboard computer, and signals to control the scene generators. Scene depiction in the Gemini era still depended on the use of television cameras and fake "spacescapes", as in aircraft simulators. Models or large photographs of the earth from space provided scenes that were picked up by a television camera on a moving mount. Signals from the computers moved the camera, thus changing the scene visible from the spacecraft "windows," actually CRTs. A planetarium type of projection was also used on one of the moving-base simulators at Johnson Space Center to project stars, horizon, and target vehicles.

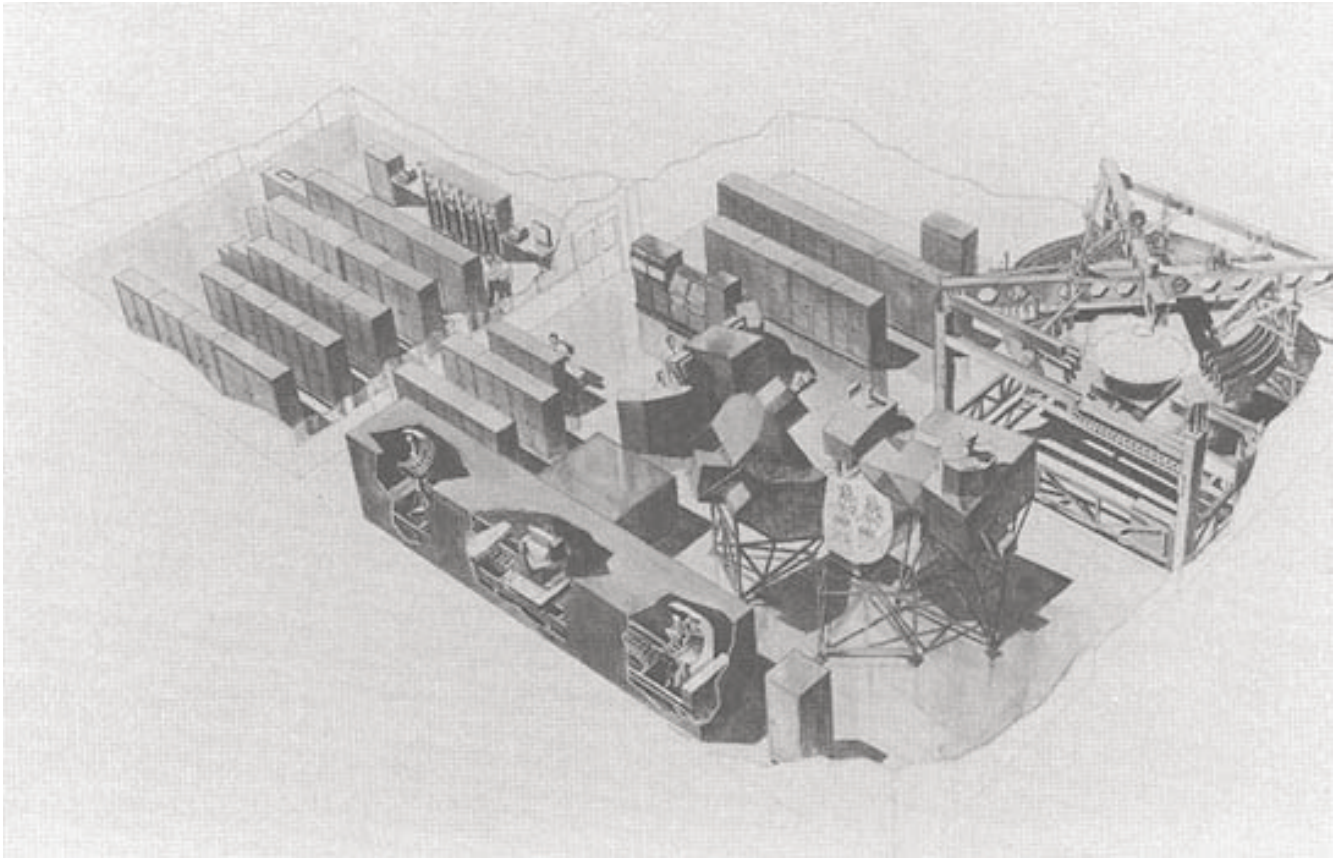


F-18 simulator at NASA Dryden Flight Research Center in Edwards California

The visual images for the Apollo trainers, and the later Shuttle and Skylab trainers, moved to an entirely digital control. Window scenes were entirely computer generated. Coupled with sophisticated **image processing** techniques, the simulations could not only represent the environment of Earth and near space, but also the surfaces and environments of the moon and Mars and other celestial bodies.



The Apollo Command Module Mission Simulator



An artist's conception of the Apollo Lunar Mission Simulator (Images in this section are used courtesy of NASA.)? http://history.nasa.gov/computers/Ch9-2.html

Movie 13.4 NASA Flight Simulation – 2004



Flight Simulators – A Safer Way to Test
https://www.youtube.com/watch?v=QA1is2UtQnw

13.5 Military





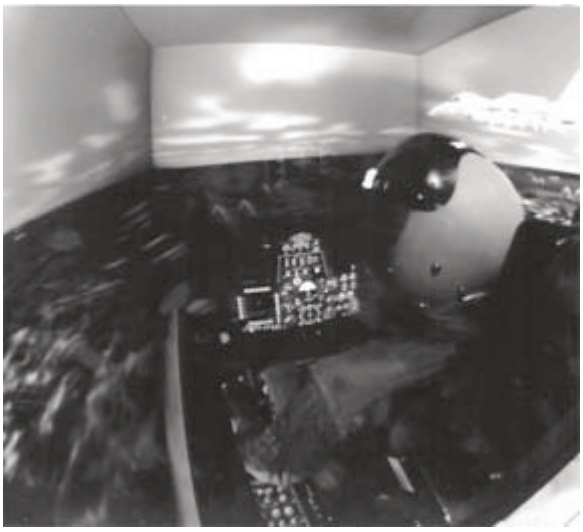
NTSC Head Mounted Display

The U.S. Navy maintained an active simulation activity, particularly at their Naval Training Systems Center in Florida. Most notable was the early development on their VTRS, or Visual Technology Research Simulator. This simulator was an example of a “target tracked” system, which placed an image of the air-to-air combat target dynamically in a larger scene, in this case on a spherical screen surrounding the trainer cockpit. In the interest of computation speed, the area of most visual interest (the target and its nearby surroundings) was rendered in higher detail, and inset into a lower resolution background display representing the surrounding terrain outside of the interest field of view.

NTSC also developed a head mounted display for American Airlines that used the target tracking approach that was also developed by Singer-Link in their ESPRIT (Eye-Slaved Projected Raster Inset) system.The NTSC system used eye and head tracking technologies, and projected from a lens on the helmet, so the higher resolution image was always coordinated with the pilot’s view.

The Air Force was also interested in low altitude simulation of high resolution, high detail terrain. Their ASPT (Advanced Simulator for Pilot Training) installed in 1974 at Williams AFB in Arizona was one of the first examples of a multiple display, multiple CGI channel “butted” display system, which was the model for most simulators built during the 1980s and 1990s. The field of view was divided between multiple CRTs surrounding the pilot, each fed with a signal from an independent but synchronized computer image generator. By aligning the boundary of one display with that of the adjacent, it gave the feel of a continuous image. The ASPT used seven

CRTs with complex optics to eliminate overlapped images, in what they called the “Pancake Window” (Farrand Optical Company). Each pentagonal window provided more than an 86° field of view.



Boeing Visual Integrated Display System

An alternate approach emerged from the Air Force Resource Laboratory. The Pancake Window mosaic display was becoming difficult to maintain. Seeking a low cost, full color replacement for the dim, monochrome Pancake Window led to experiments with rear projection screens and CRT projectors. A bright, clear real image was formed at approximately arm’s length from the pilot’s eye. An example of this technology was the Boeing VIDS (Visual Integrated Display System.)

The E&S CT5 and CT6 systems are configured like the ASPT system. The early CT5, coupled with the Rediffusion physical simulator, cost around $20M. Other similar systems included the GE Compuscene IV made for Martin Marietta and the DIG from Singer-Link.

13.6 Other Approaches





GE Cell Texture

Researchers experimented with many different approaches to the generation of complex imagery for simulation. The Low-resolution environment coupled with the hi-resolution targets described in Section 5 gave only moderately acceptable results. Hardware, like that developed at E&S and elsewhere, made image generation faster, as did algorithms that were embedded in the software. General Electric used texture mapping to achieve reasonable results, as shown in the GE Cell Texture shown here.



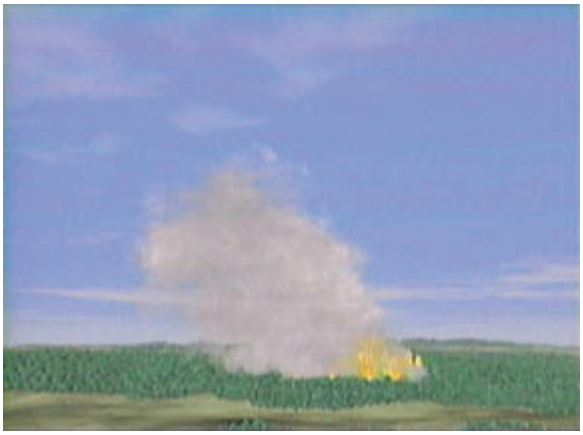
Honeywell Flight Simulation

Honeywell experimented with assembling real images stored on video discs, and retrieved, transformed and seamed them together based on the desired field of view and range in real time.

Vought researchers experimented with creating a mosaic of images obtained from aerial photographs into a terrain data base. A similar approach took advantage of the data bases of the Defense Mapping Agency, which can combine **height maps** representing elevations (for the geometry) with terrain and cultural artifacts.



Gardner's ellipsoid approach to representing trees, clouds, fire and smoke.



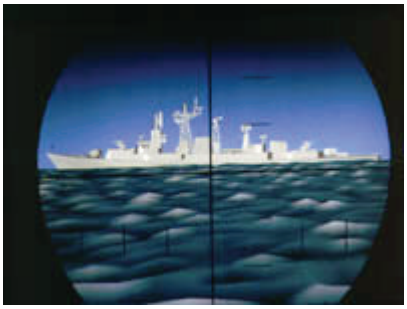
Gardner's ellipsoid approach to representing trees, clouds, fire and smoke.

Another interesting approach is attributed to Geoff Gardner at Grumman Data Systems, for the generation of terrain data and effects in simulations. Gardner presented a method to generate terrain, clouds and other objects in a SIGGRAPH 84 paper, realistic smoke and clouds in a 1985 paper, which he extended to smoke and fire in a 1992 paper.The models he presented used quadrics or **ellipsoids** (which are very computationally inexpensive for things like view intersection) that were covered using a texture derived as a function of the transmittance of transparency each ellipsoid should possess. The transmittance of transparency varied from the center of the object to the edges of the ellipsoid as a mathematical function. Gardner was able to use these ellipsoids and transparent textures to model the terrain, trees, clouds, smoke, fire and other elements.



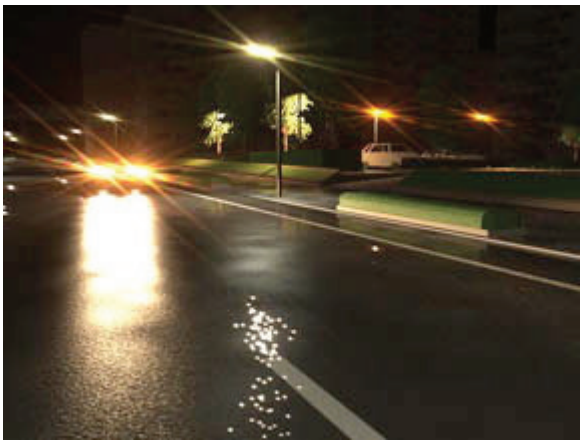
Nighttime driving simulation

Evans and Sutherland, as well as other simulation manufacturers, and researchers in simulation as well as CGI in general extended the ideas of flight simulation to other vehicles, including maritime and automobile. For example, In the mid-80s, NTSC contracted with Ohio State to



Ohio State University submarine pilot training simulator

develop a submarine pilot simulation trainer for pilots who maneuver the ships into dock at the Norfolk base in Virginia.



Hiroshima University lighting simulation

Nakamae at Hiroshima University experimented with accurate lighting approaches to represent night time driving scenarios.

Movie 13.5 Beethoven's Sixth in CIG

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/beethoven-2.m4v

Animation by Geoff Gardner, using his system of textured quadric surfaces for scene generation for flight simulation purposes (1984)

Microsoft Flight Simulator

Bruce Artwick was a student in Electrical Engineering at the University of Illinois in the mid 1970s when he became interested in the connection of emerging computer systems and airplane flight. His 1975 thesis, "A Versatile Computer Generated Dynamic Flight Display" showed how the computer display could effectively be used to demonstrate the flight of an aircraft. Artwick developed the code for the first consumer flight simulator that ran on the Apple II. Interest from the consumer market motivated him to start a company, SubLogic, that developed simulators that ran on the TRS-80 in 1980. In 1982, SubLogic released a version of the simulator for the IBM PC, called Microsoft Flight Simulator 1.0. He also developed for the Commodore 64, the Amiga and the Atari platform.

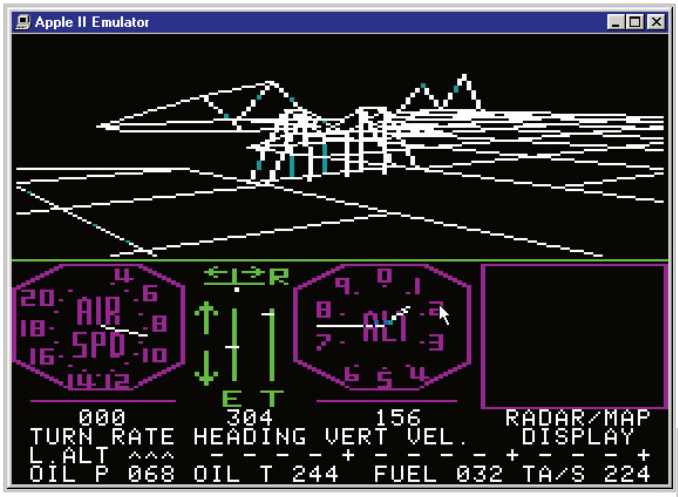
Several versions of Flight Simulator followed, and some say that it contributed to increased sales of computers because its graphics and CPU demands required more sophisticated computers. These later versions contained additional aircraft types, better landmarks, cities and scenery, multiple airports,and as of version 3.2, allowed the viewer to see the aircraft from outside of the cockpit. The software later included a Professional version with more capabilities, and a kiosk version to be run in public places.
This very popular program (an estimated 21 million copies were sold by 1999) was one of the most successful software titles in history. Shortly before the version for Windows 95 was released, Artwick sold his company to Microsoft. They continued to expand the program until they closed the division in 1999.

Movie 13.6 Microsoft Flight Simulator



Video history of the Microsoft Flight Simulator on the PC *https://www.youtube.com/watch?v=ICb9ZXiD3q4*

Gallery 13.2 Screenshots from Microsoft Flight Simulator







Images: Screenshots from various versions of the Microsoft Flight

Simulator.



Chapter 14: CG in the Movies

CG in the Movies

After the movie *TRON* had such difficulty at the box office, there was hesitation to embrace the emerging technology in the motion picture industry. But special effects were desirable, and *The Last Starfighter* showed the value of using this approach to adding scenes to movies, and the usage escalated from there.



Flight of the Navigator – Viking Films (1986)

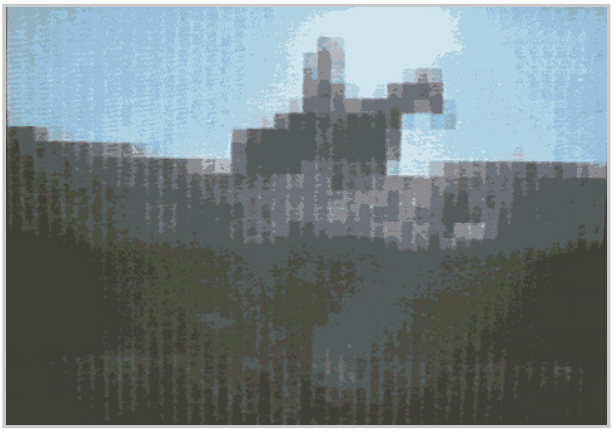
14.1 Introduction



As the image making capabilities advanced during the move from the lab to full scale production in the 1970s, Hollywood took notice. There were several movies that included one or more special effects scenes that were CGI.

For example, John Whitney Jr. produced some graphics effects for Michael Crichton's *Westworld* in 1973 – in particular, the "robot view" of the main character was the first example of digital image processing used in films;





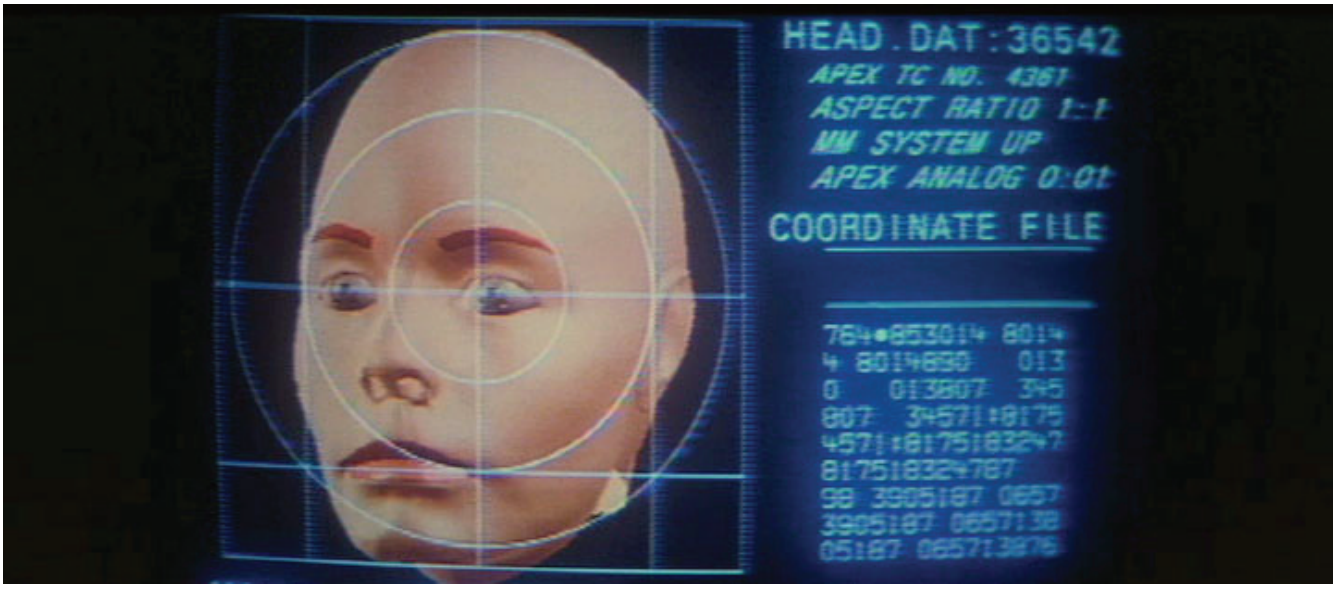
Yul Brynner played the android in the Westworld western theme park, and his pixellated view is shown at the right.

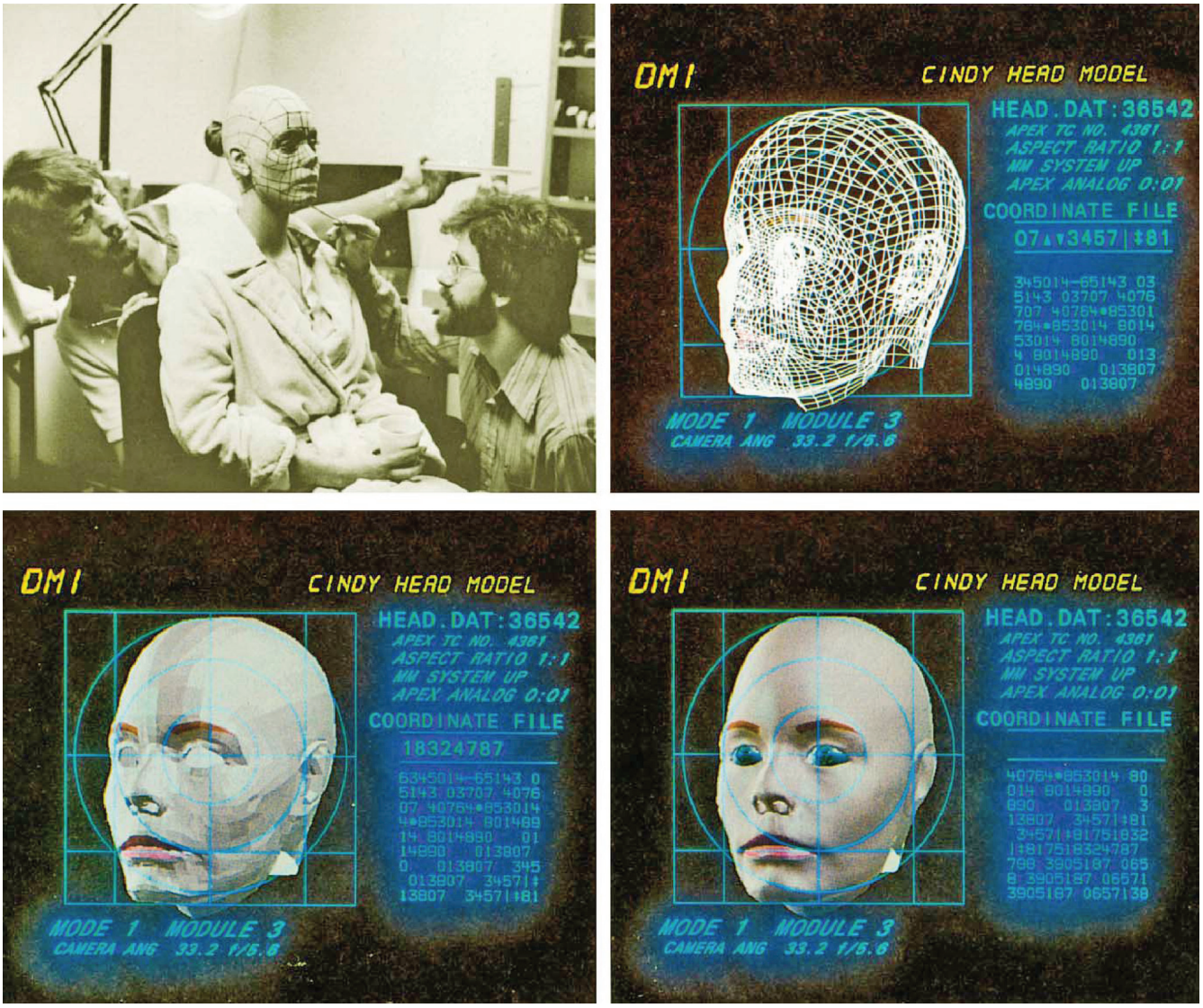
Information International Inc (III) produced a 3D representation of Peter Fonda's head for the movie *Futureworld* in 1976;



Peter Fonda digitized for 3D model

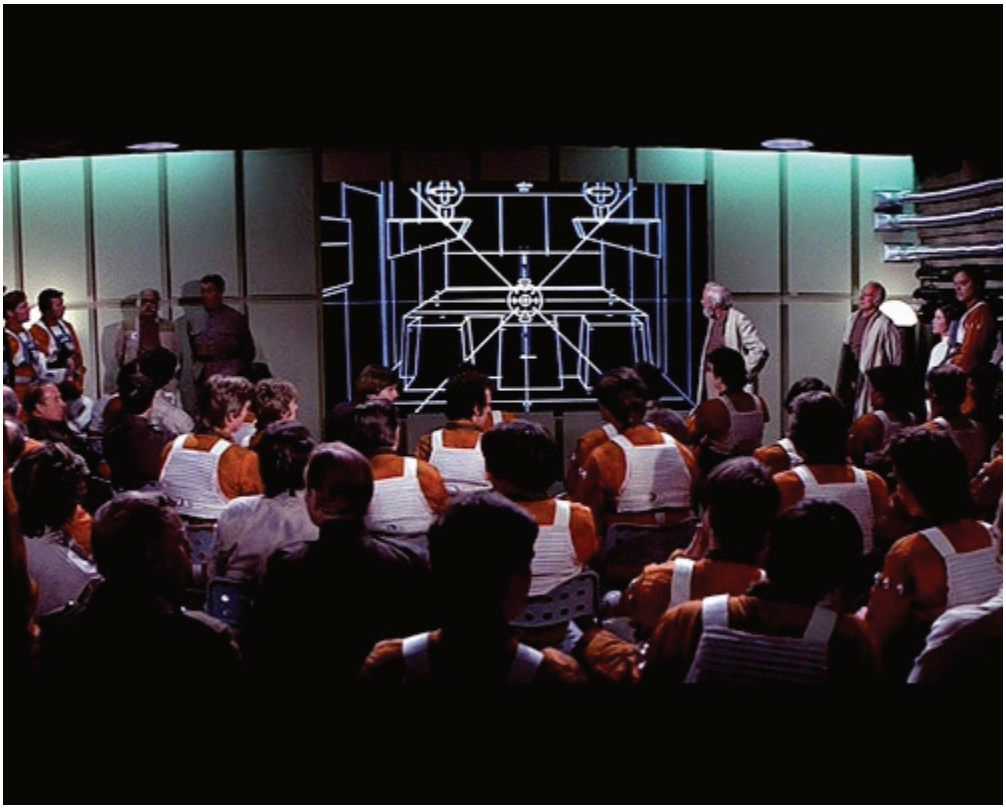
Susan Dey was digitized by III for several scenes in Michael Crichton's 1981 film *Looker*;





Cindy's head from the movie Looker (1980). Actress Susan Dey is digitized from reference lines by Art Durinski and Larry Malone.

Larry Cuba produced a scene for *Star Wars* using Tom DeFanti's software at the EVL at University of Illinois in Chicago, and another scene was done with SCANIMATE;

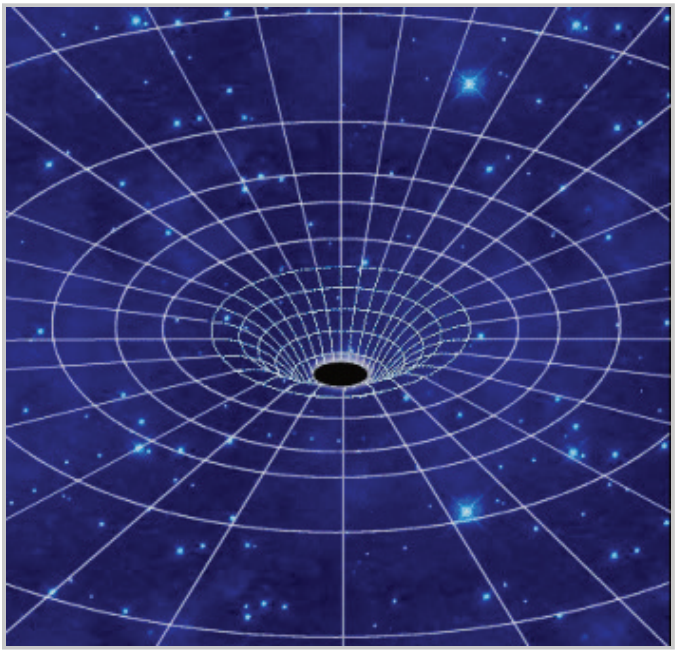


Larry Cuba graphics for Star Wars

John Whitney, Sr., R/Greenberg and others produced graphics for titles, including the famous *Superman* titles; Disney's *The Black Hole* used a 3D effect for the opening and for some trailers;



Superman opening title

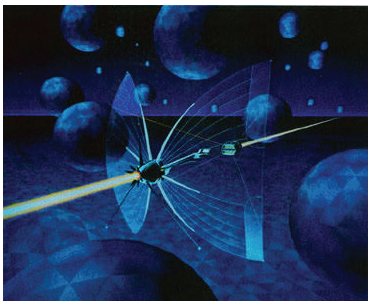


Black Hole graphics

the "Genesis Effect" was produced by Lucasfilm for *Star Trek: the Wrath of Khan* in 1982.



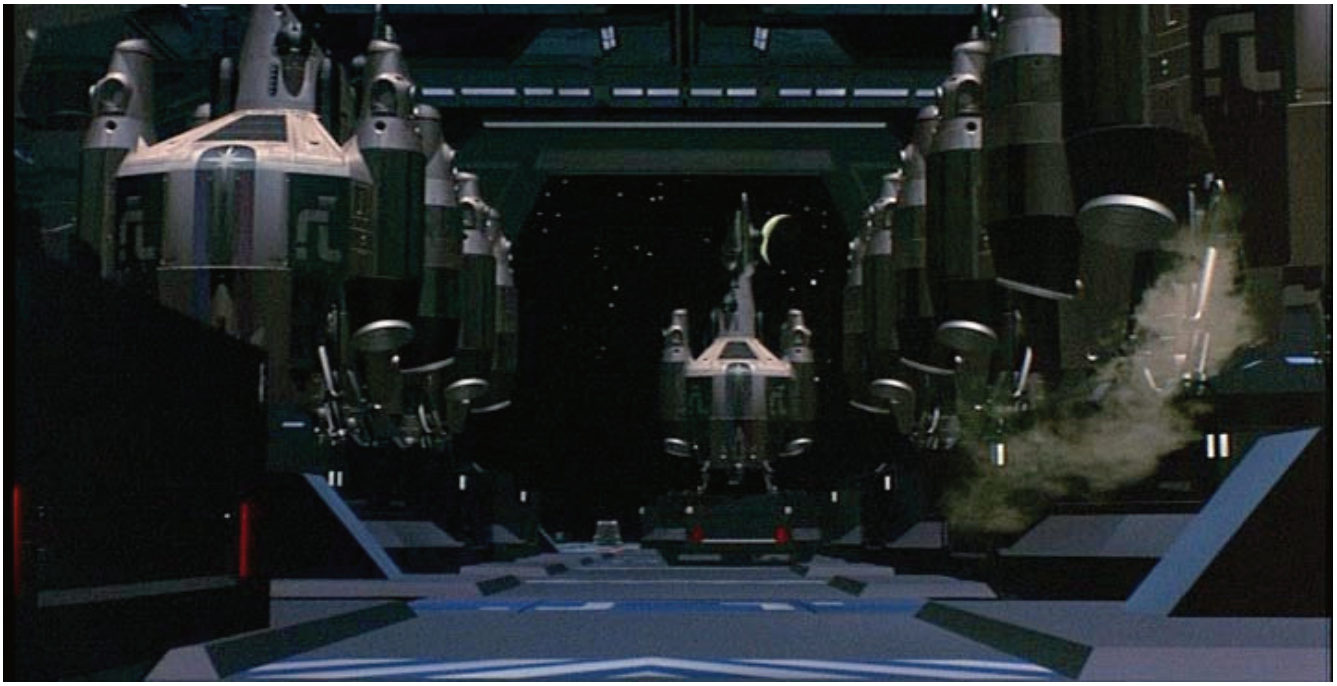
Genesis Effect (1982)



TRON Solar Sailor

But it was the 1982 sci-fi movie *TRON* that pushed the issue, using four major production companies to produce over 20 minutes of full 3D graphics. Whereas the movie was not a box-office success, it did prove that this new medium had tremendous potential for the industry. Read more details about this movie and the effects production In Section 3.

The cost of *TRON*, coupled with its poor performance at the box office, caused Hollywood to take a step back from CG film production. They became excited once more when Digital Productions produced the tremendous imagery for the movie *The Last Starfighter*.



The Last Starfighter – Universal Pictures (1984)

Read more about the production of *TRON* and *The Last Starfighter* in the article *Science and the Silver Screen* from the Time-Life series *Understanding Computers: Computer Images* (1986).

The CGSociety and 3D World presented *a rundown of the Top 100 3D Movies* as selected by the CG community in 1998.

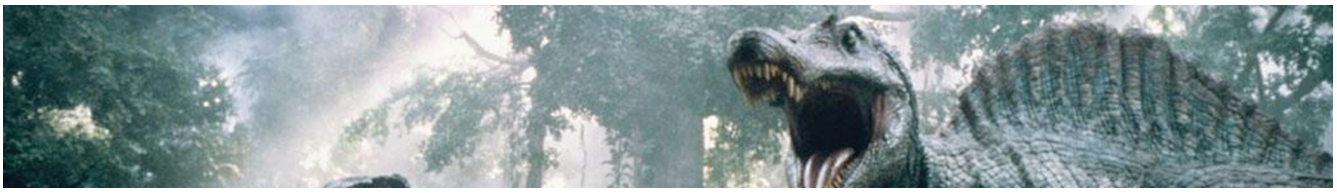
Greatest Visual and Special Effects (F/X) – Milestones in Film
from THE GREATEST FILMS – The "Greatest" and the "Best" in Cinematic History website

Movie 14.1 Animated Characters in the Movies



https://vimeo.com/14437767

14.2 CGI and Effects in Films and Music Videos



The following writeup, titled The History of Computer Graphics and Effects, *was written by Matt Leonard of Digital Dreams & Visions in 1999. He included it on his website, which is inactive.*

From the very early days of man's creation it seems he has been fascinated by the world around him. Early cave paintings show the very first artistic expression of man's desire to represent this world, showing not only the very form of creation but the living qualities of movement as well. This art form has been developed and diversified over the centuries until the establishment of the motion picture industry in the late 1800s. The first ever special effect or Illusion, as they were known then, was produced in 1895 by Alfred Clark in *The Execution of Mary Queen of Scots*.

1900s and 1910s



George Méliès: A Trip to the Moon

Around the turn of the century, the French magician George Méliès released his first film *Indian Rubber Head* (1901) bringing his own form of magic to the big screen. The following year he released *A Trip to the Moon* (1902) and *The Dancing Midget* (1902), using almost every type of special effects trick still used today.

Effects continued to become more elaborate throughout the next twenty years, through people such as Robert W. Paul and Edwin S. Porter. The technique of using mattes to composite several images onto one negative was employed in such films as *The Great Train Robbery* (1903) and *The Motorist* (1906).

1920s



The Lost World

By the mid 1920s things began to change. Willis O'Brian's stop motion hit theaters in 1925 in the form of *The Lost World*, while a year later Fritz Lang's *Metropolis* (1926) took the effects industry by storm. The Schüfftan Process artfully employed in *Metropolis* and other movies, utilized **forced perspective** techniques to create an illusion of size and distance. Such techniques are still common today, being used in such films as *Mighty Joe Young* and *Armageddon* (1998).



Metropolis

Alongside this, MGM developed the Composite Reduction process, allowing previously photographed footage to be inserted into specific areas of another frame, as in *The Hunchback of Notre Dame* (1923), *The Ten Commandments* (1923) and *Ben-Hur* (1926).

1930s and 1940s



King Kong

The effects industry continued to grow through the 1930s with such films as *King Kong* (1933) and *Gone with the Wind* (1939). In 1934 Walt Disney's *Snow White* arrived, ushering in a new era of full-length animated films.

1950s



SAGE

The post-war years of the 1950s moved the focus of film to outer space, and with the development of the Motion Control Rig by Paramount, more sophisticated shots were developed. Meanwhile the SAGE Machine (Semi-Automatic Ground Environment) was created to follow enemy fighter planes during the Cold War. This provided the first interactive computer graphics. Some of the outstanding effects films of the 50s included *Destination Moon* (1950), *War of the Worlds* (1953) and *Forbidden Planet* (1956). The **Blue Screen** technique was also invented, enabling a person or object to be filmed against a blue, green, or sometimes red background, and then extracted and composited against a different background.



Forbidden Planet

1960s



Jason and the Argonauts

There was little technical development during the early 1960s. Ray Harryhausen's *Jason and the Argonauts* (1963) came out, which included the famous **Stop-Motion** skeleton battle sequence which is still inspiring filmmakers today (e.g. *The Mummy* (1999)). 1963 saw the first Academy Award given for Best Visual Effects, won by Alfred Hitchcock's *The Birds*. Then in 1968 Stanley Kubrick's *2001: A Space Odyssey* (Oscar winner), began to push the boundaries of special effects once again.



2001: A Space Odyssey



Sketchpad

Although the FX industry had not moved forward tremendously until the late 60s, the computer graphics industry had made headway. Ivan Sutherland had invented the Sketchpad interactive graphics software in 1962 and the University of Utah had opened the first CG department in 1966. 2D morphing techniques were first developed in 1967 at the University of Toronto, along with the development of Environmental Reflection Mapping (1976) and Bump Mapping (1978) by James Blinn. Triple-I created the first feature Film appearance of 3D CG, while in 1968 Ivan Sutherland and David Evans joined forces to open the worlds first CG company, Evans & Sutherland, still going strong today. 1968 also saw the arrival of Ray Tracing developed by Bell Labs and Cornell University.



Jim Blinn

1970s

During the 1970s technology within computer graphics continued to grow, pushed forward by pioneers such as James Blinn and David Em. **Bezier curves** (1970) were invented along with both **Gouraud** (1971) and **Phong shading** (1975). 1975 saw the development of a CG teapot that has now become the computer graphics icon. Ed Catmull went on to develop texture mapping in 1974, refined later in 1976 by James Blinn. Bill Gates founded Microsoft while Steve Woznick and Steve Jobs built the first Apple Computer. Also Quantel created Paintbox, the first graphics product aimed specifically at the broadcast industry.

George Lucas formed Industrial Light and Magic (ILM) to cover the huge array of special effects for his new film *Star Wars* (1977) (Oscar winner). Among those who joined were Dennis Muren, John Dykstra and Richard Edlund. A host of films began to appear utilizing CG, including *The Black Hole* (Oscar nominated) and *Alien* (1979) (Oscar winner). Also in that year Ed Catmull left NYIT and joined ILM to head up their CG department.



Star Wars

1980s



TRON

In the 1980s, Triple-I continued their work, producing seven minutes of CG for *Looker* (1980), while ILM produced the first all-digital CG image for *Star Trek II: The Wrath of Khan* (1982).

Disney's *TRON* (1982) was the first extensive use of 3D CG.

Where the Wild Things Are (1982-83) was a pioneering 35mm film test, which digitally composited 3D CG backgrounds with traditionally animated (digitally inked and painted) characters. The work was led by Chris Wedge (now vice-president of Blue Sky/VIFX, (*Joe's Apartment*, *Star Trek: Insurrection* and *Bunny*). John Lasseter (director of *Toy Story*, *A Bugs Life* and *Monsters Inc*.) left Disney and joined Lucasfilm Computer Graphics Division, working on the CG Endor moon sequence for "*Return of the Jedi*" (1983) (Oscar winner).

SGI (Silicon Graphics Inc.) was founded by Jim Clark in 1982 and by 1984 they had released their first product, the IRIS 1000. The early 80s also saw a surge in the opening of graphics software houses and the release of new products onto the market. These included 1983: Alias Research Inc. (Alias/1), 1984: Wavefront (PreView), 1985: Softimage (Creative Environment) and 1982: Autodesk (AutoCAD).



Young Sherlock Holmes

Between 1980 and 1985 the special effects and computer graphics industries began not only to settle down but also to merge slightly. Richard Edlund left ILM in 1983 and formed Boss Film Corp., powering onto the market with effects work for *Ghost Busters* (Oscar nominated) and *2010* (1984) (Oscar nominated). Lucasfilm Computer Graphics Division released *The Adventures of Andre and Wally B*, directed by John Lasseter. Disney's *The Black Cauldron* (1985) became the first animated feature film to contain a 3D element. Lucasfilm Computer Graphics Division produced the 3D animation required to bring to life a knight made of stained glass for the film *Young Sherlock Holmes* (1985) (Oscar nominated). The project was also the first to composite CG with a live-action background. Dennis Muren was the Visual Effects Supervisor.

In 1986 Pixar was formed when the Lucasfilm Computer Graphics Division was purchased from George Lucas by Steven Jobs for $10 million. The pioneers included John Lasseter, Ed Catmull and Ralph Guggenheim. The company went on to produce the famous Renderman software and animated features including *Luxo Jr.* (1986) (Oscar nominated), *Reds Dream* (1987), *Tin Toy* (1988) (Oscar winner), *Knick Knack* (1989), *Toy Story* (1995) (Oscar winner), *A Bug's Life* (1998), *Toy Story II* (1999), *For The Birds* (2000). (More about Pixar can be found in Chapter 11.)



Pixar Movies

Howard the Duck (1986) was the first film to use digital wire removal and the first work carried out by the new ILM computer graphics department. Later that year they also worked on *Star Trek IV: The Voyage Home* (1986) which contained the first use of 3D scanning by Cyberware on a film. During the following year Arcca Animation produced *Captain Power and the Soldiers of the Future* (1987). It was the first TV series to include characters modeled in 3D entirely within the computer.



The Abyss

By the end of the 80s things were beginning to steam ahead. ILM won another Academy Award for *Who Framed Roger Rabbit*, and completed the first digital morph for *Willow* (1988) (Oscar nominated). The following year ILM produced the Donovans destruction sequence for the end of I*ndiana Jones and the Last Crusade* (1989). The shot involved scanning multiple film elements into the computer, digitally compositing them together and then scanning back out to film. Also in that year, ILM produced the water pseudopod creature for "*The Abyss*" (1989) (Oscar winner). The software used included Alias/2 and Photoshop. Dennis Muren, Mark A.Z. Dippe and John Knoll were some of the brains behind the success of the project.

1990s

As we move through the final decade towards the next millennium, the Computer Graphics and Special Effects Industries continue to break new boundaries and bring us the most spectacular array of visual imagery to date.

One of the newer CG companies to appear towards the end of the 80s was Rhythm & Hues. They produced over 30 shots of photorealistic airplanes, bombs and smoke all in daylight for a film *Flight of the Intruder* (1990). Another new company, deGraf/Wahrman, produced the first CG simulator ride that same year called The *Funtastic World of Hanna-Barbera*. They also produced the CG head of the robot villain for *Robocop 2* (1990).



Shutterbug

Disney produced the first completely digital film in the shape of *The Rescuers Down Under* (1990) and ILM painted the first digital Matte Painting for the film *Die Hard 2: Die Harder* (1990). The film also contained extensive Blue Screen Compositing for a sequence in which Bruce Willis is ejected out of a plane's cockpit. Pixar used their new Photorealistic Render software, Renderman, to produce the famous "Shutterbug" image. Autodesk released 3D Studio v1, their own 3D modeling and animation software.



Terminator



Dennis Muren, Steve Williams, Mark Dippe & Eric Armstong – ILM

1991 marked the beginning of the ground breaking years. James Cameron's *Terminator 2: Judgment Day* (Oscar winner) brought to life by the artists at ILM began to change the way Hollywood perceived computer graphics. It was the first major digital character to be used in a film since the stained glass knight in *Young Sherlock Holmes*. Alias/2 and Photoshop were used along with a host of in-house tools designed especially for the project. Dennis Muren, Mark Dippe, Stefen Fangmeier, Tom Williams and Steve Williams were some of the people involved. Another major contribution that year came from Disney's *Beauty and the Beast*; the ballroom sequence contained a complete 3D rendered background. Stop Motion was superseded by Go Motion created by Phil Tippet for *Dragonslayer* (1991).

During 1992 ILM continued to push the boundaries in *Death Becomes Her* (Oscar winner), creating photorealistic skin. Walt Disney also continued to push their techniques in both *Aladdin* and their short in-house project *Off His Rocker*. Also Virtual Reality hit Hollywood in the form of the *Lawnmower Man* (Angel Studios).



Jurassic Park

Various things happened the following year, but all were overshadowed by the release of Steven Spielberg's *Jurassic Park* (1993) (Oscar winner). ILM employed a huge range of tools to create CG dinosaurs and various other special effects needed for the film. These included Alias PowerAnimator, Softimage 3D, Matador and Lightwave (for simple animatics). 1993 also saw the rise of Digital Domain formed by James Cameron, Stan Winston and Scott Ross.

1994 saw a significant rise in films containing CG. This included *Forest Gump* (ILM) (Oscar winner), *The Flintstones* (ILM), *The Mask* (ILM) (Oscar nominated), *The Lion King* (Disney), *Timecop* (VIFX), *The Shadow* (R/Greenberg Associates) and *True Lies* (Digital Domain) (Oscar nominated). Also Mainframe Entertainments *Reboot* came out as the first 100% CG television show. Microsoft bought Softimage, and the computer game *Doom* was released.

During 1995 SGI acquired both Alias and Wavefront combining the two companies into Alias/Wavefront. In the film industry, *Toy Story* (Pixar) became the first full-length 3D animated film. *Judge Dredd* (Kleiser-Walzack

Construction Company) became one of the first films to incorporate CG stunt doubles along with *Batman Forever* (Warner Bros.). ILM released *Jumanji*, further developing their ability to produce photorealistic hair, and *Casper*, the first CG characters to take a leading role. Rhythm and Hues *Babe* won an Academy award for its special effects. Steven Spielberg, Jeffrey Katzenberg and David Geffen joined together to form Dreamworks SKG, and the Sony Playstation was released, and *Apollo 13* was released.

By 1996 *Dragonheart* (Oscar nominated) was finished. Rob Coleman of ILM oversaw hundreds of shots of the talking dragon, Draco, achieving not only a full range of emotional expressions but also the ability to talk. The breakthrough Caricature software or Cari for short, had been developed by Cary Philips and has now become one of ILMs main in-house tools. ILM also relied heavily on Alias/Wavefronts Dynamation particle system software for the movie *Twister* (Oscar nominated).



Hunchback of Notre Dame

Disney's remake of *The Hunchback of Notre Dame* used CG to produce crowds, props and other effects. Among the other big films to contain computer animation were *Space Jam* (Warner Bros.) combining traditional animation with live action, and *Independence Day* (Oscar winner). The computer game Doom was superseded by Quake, and Autodesk released 3D Studio MAX.



Titanic

Alias/Wavefronts Dynamation particle system was again used in 1997 by ILM in the creation of a CG cape for *Spawn* together with realistic goo, drool and saliva. George Lucas restored Episodes 4, 5 and 6 of the *Star Wars* saga; over 350 shots were modified or added to the existing footage. James Cameron's company Digital Domain created a huge number of shots for *Titanic* (Oscar winner) which included extensive use of Motion Capture.

Other CG movies in 1997 were *Dante's Peak*, *Starship Troopers*, The Lost World: Jurassic Park, and *The Fifth Element*.

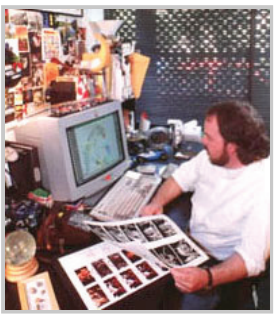












Pixar won an Academy Award (in March 1999) for *Geri's Game* (1998) which utilized Subdivision surfaces. Radiosity Rendering was used in the creation of *Bunny* (1998) (Blue Sky/VIFX) which also won an Academy Award the same year. 1998 seemed to be a year of animation involving animals with *A Bugs Life* (Pixar) and *Antz* (PDI). Chris Landreth received a Genie Award for his contribution to *Bingo*, the test project used on the newly released Maya character animation and special effects package from Alias/Wavefront.



aaa

1999 was an excellent year for both computer animation and special effects. In May George Lucas released the long awaited *Star Wars Episode 1: The Phantom Menace*, containing almost 2,000 digital effects created by Industrial Light & Magic under the supervision of Dennis Muren, John Knoll, Scott Squires and Rob Coleman. This was without question the biggest computer animation and special effects film thus far in history. Among the digital tools used to create this ground breaking achievement were PowerAnimator, Maya, Softimage 3D, Commotion, FormZ, Electric Image, Photoshop, After Effects, Mojo, Matador, and RenderMan. Various proprietary in-house software packages were also used including Caricature, Isculpt, ViewPaint, Irender, Ishade, CompTime and Fred.

Among ILM's other contributions this year are *The Mummy*, *The Haunting* and *Wild Wild West*. Other major effects movies this year include *The Matrix*, whose special effects were created by Manex Visual Effects, *Toy Story 2* (Pixar), *Supernova* (Digital Domain), *Deep Blue Sea* (Hammerhead) and *Lake Placid* (Digital Domain).



Jar Jar Binks

As we move into the next millennium, one of the big questions which is often asked within the computer animation and effects community is "what is the next big thing?" Jar Jar Binks from *Star Wars Episode 1: The Phantom Menace* (ILM) (1999) was the first photorealistic all digital main character in a feature film. People are still fascinated by the concept of entirely digital photorealistic humans. With the improvement in both hardware and software our ability to create more and better digital characters improves by the year.

Some people argue that various questions need to be asked before a huge amount of effort is put into one relatively small area of the industry. Elvis was Elvis not because of how he looked but because of how he moved and acted. There are hundreds of Elvis impersonators in the world, some of which are very good, but none of them are good enough to fool us into thinking Elvis has returned. The closer we get to creating a completely digital character the more our senses seem to alert us to the fact that something is not completely right and therefore we dismiss it as a cheap trick or imitation.



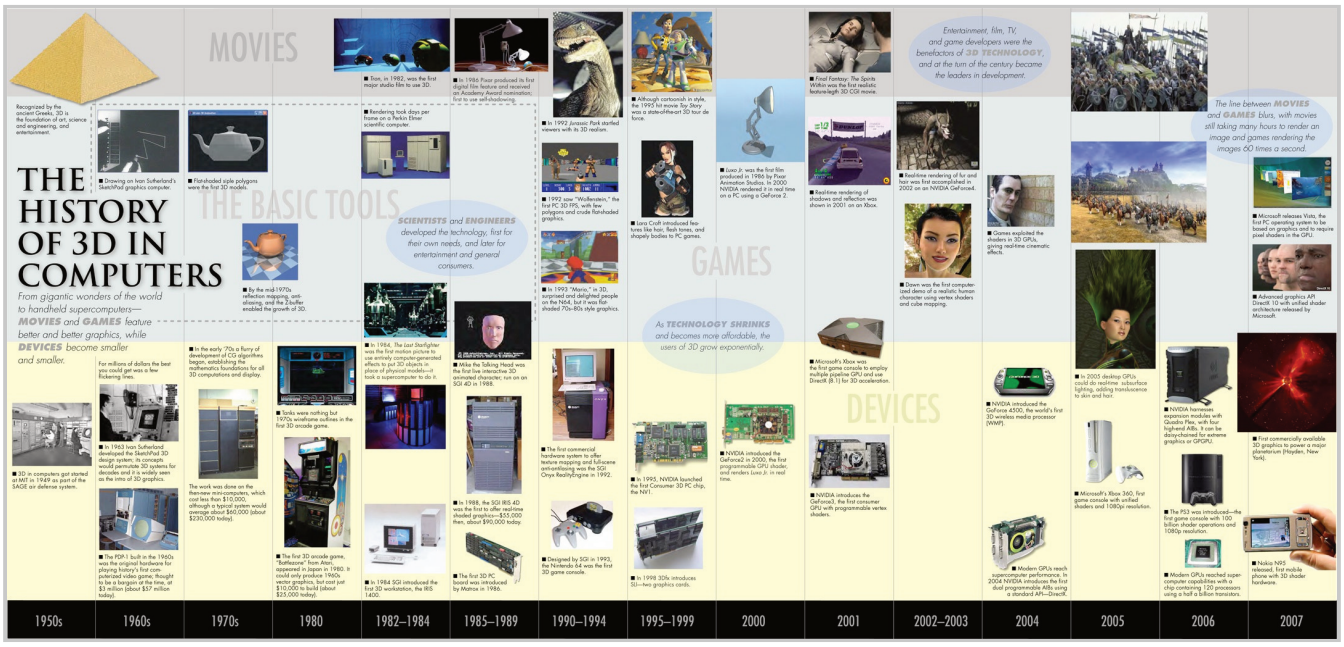
The Matrix



What Dreams May Come

There are no doubt many reasons for using digital humans, such as for stunt stand-ins or simply for those impossible situations conjured up by Hollywood, but as Dennis Muren of ILM once said, "Why bother! Why not focus on what doesn't exist as opposed to recreating something that is readily available." Over the last few years we have begun to see animation and special effects creating more impossible situations such as the Flow-Mo and Bullet Time effects shots of *The Matrix* (1999) and the beautiful artistic style of *What Dreams May Come* (1998).

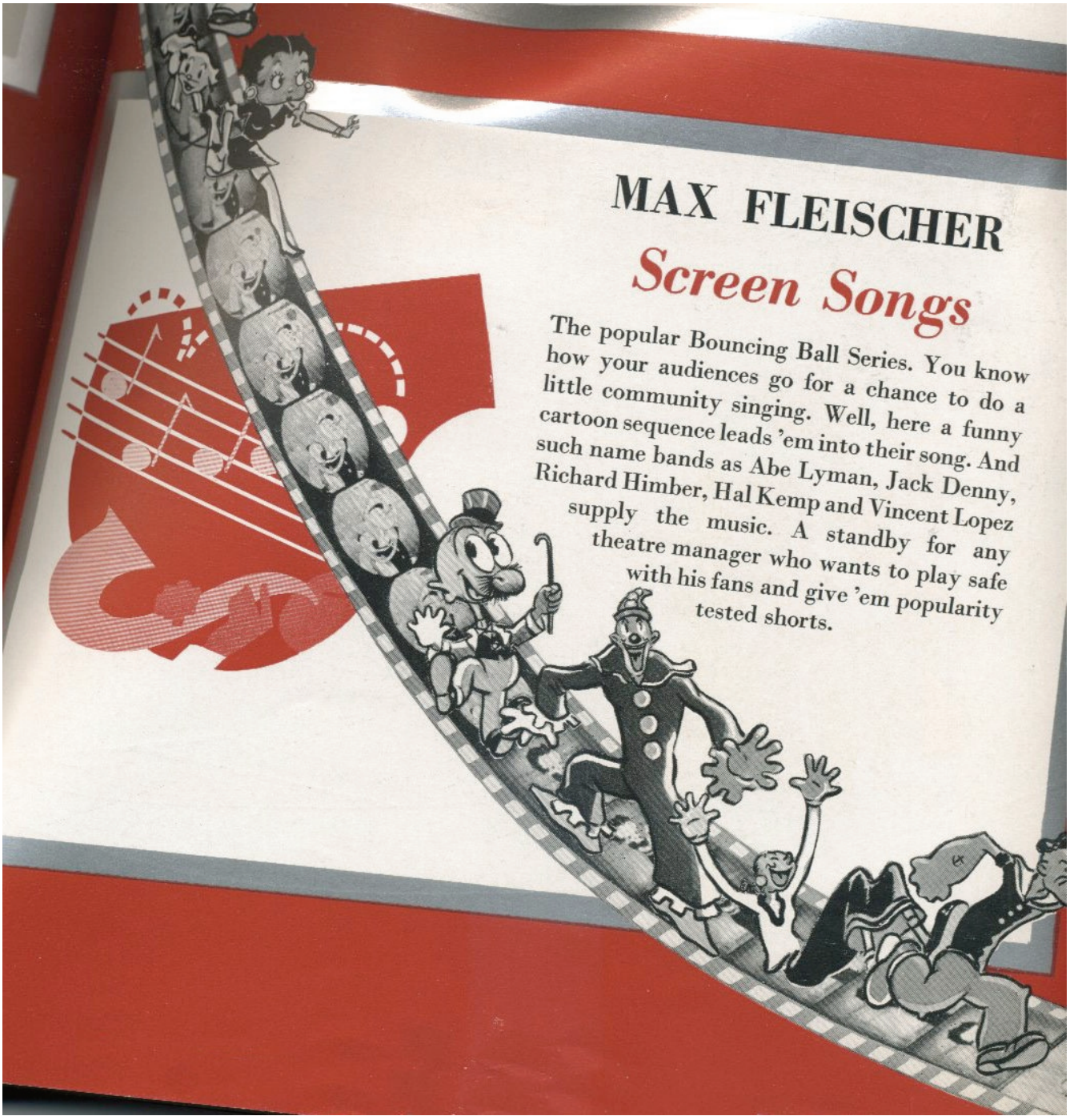
Hollywood has found there to be a huge shortage of dinosaurs, dragons, Gungans and various other creatures and characters needed for lead roles in todays motion pictures. A lot of people are very keen to see the progression of digital creatures taken to its logical conclusion of human beings, while others say the focus should be on more artistic effects. Whatever your opinion is, you can be sure of one thing: the magic of computer animation and special effects will continue to advance even faster into the next millennium as a tool to bring to life the dreams of storytellers.



Poster attributed to Jon Peddie Research (http://jonpeddie.com)

Music Videos

Another film-making effort (closely aligned with movies) that utilizes CG special effects is the creation of music videos. The intent of music videos has always been to promote a song or album, or as an artistic expression of a band or artist. They date back to the early commercial music era of the late 1920s and early 1930s. For example, Max Fleischer's patented *Screen Songs*, much like "Sing Along with Mitch" of the early 1960s, were produced as sing alongs for the audience, using the bouncing ball as a way to keep the viewer connected to the music.



Early 1930s cartoons, such as the Disney *Silly Symphonies* or *Fantasia*, featured musicians performing in live action or recorded shorts in conjunction with the cartoons. Warner Brothers often featured short musical numbers to promote their upcoming films.

Movie 14.2 Disney Silly Symphony Farmyard Symphony (1938)



https://www.youtube.com/watch?v=ni4iZJ2NU-I

Rock groups of the 1960s and 1970s used the genre to promote their music, often filming at live concerts or lip-syncing in different environments. Some people point to the Beatles *Hard Days Night* as the real launching pad for music videos, but many acknowledge that it was Queen's *Bohemian Rhapsody* that really was the video that convinced the industry of the potential for this art form.

Movie 14.3 Queen – Bohemian Rhapsody – 1975



https://www.youtube.com/watch?v=irp8CNj9qBI

Michael Nesmith of the Monkees developed a TV show to feature music videos, called *PopClips*, in the late 1970s. It was tested on Warner's QUBE cable network in Columbus, Ohio. Nesmith later produced an award winning compilation called *Elephant Parts*, and a show that aired in 1985 called *Television Parts*. But the music video industry really didn't take off in a big way until 1981 with the first broadcast of MTV.

MTV Logo

Most of the music video productions during this early time used video effects, such as green screen, slit scan or other motion effects, as the special effects component of the pieces. Although there were some early music videos that used basic CG effects, the first real documented production was done by Alex Weil, Jeff Klein and Charles Levi of Charlex in 1983 for the video for the Cars song *You Might Think*.

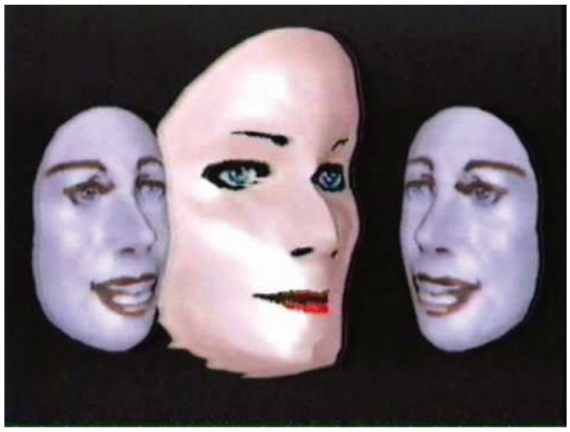
Movie 14.4 You Might Think



https://www.youtube.com/watch?v=3dOx510kyOs

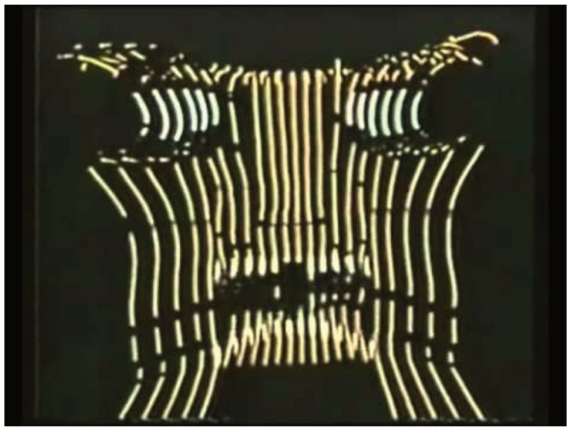
That same year Rebecca Allen at New York Institute of Technology produced talking faces (à la Fred Parke) for the Will Powers song *Adventures in Success* and CG bodies for *Smile*. (Will Powers was actually the stage name used by celebrity photographer Lynn Goldsmith when she created a self-help comedy music album entitled *Dancing for Mental Health*).

Movie 14.5 Adventures in Success



https://www.youtube.com/watch?v=j5BLHeOdvYI

Movie 14.6 Smile



https://www.youtube.com/watch?v=g43lzoRamWE

The next music video that featured CG generated characters was the video for Dire Straits' *Money For Nothing* in 1985. It has often been designated as the first music video that featured computer graphics, but that is obviously incorrect, although it was very instrumental in shaping the acceptance of the technology for use in the creation of this art-form. It was produced by Gavin Blair and Ian Pearson at Rushes Post Production using the Bosch FGS-4000 animation system and Quantel. Blair and Pearson later produced the popular *ReBoot* computer-animated series at their new company Mainframe Entertainment.



Reboot

Movie 14.7 Money for Nothing



https://www.youtube.com/watch?v=lAD6Obi7Cag

Also in 1985, Digital Productions produced the graphics for *Hard Woman* from Mick Jagger's *She's the Boss* album (although the song on the video was not the same recording from the album, as it was re-recorded by Jagger and the Hooters for this made-for-MTV video.) The video can be seen via the link in Section 4 of Chapter 6.

Many think that the 1986 video for Peter Gabriel's song *Sledgehammer* was CGI, but it in fact was produced by Aardman Animation using stop motion and claymation, much like the other Aardman production *Wallace and Gromit*. Gabriel did use computer generated animation extensively in his video for *Steam* in 1992.

Movie 14.8 Steam



https://www.youtube.com/watch?v=Qt87bLX7m_o

In 1983 Rebecca Allen at NYIT also produced wireframe graphics in the widely acclaimed video for Kraftwerk's *Musique Non Stop* from the album Electric Cafe. Allen used the digitized faces of the band to generate the images on the proprietary NYIT animation system, but the animation wasn't used immediately. It sat for three years until the album was completed and Allen reworked the imagery. The video has enjoyed frequent airing on MTV and highlight shows, and also has been regarded as a true artistic statement, having been featured in exhibitions as well.

Movie 14.9 Musique Non Stop



http://www.dailymotion.com/video/x175jh_kraftwerk-music-non-stop_music

In 1991 Pacific Data Images produced a portion of the video for Michael Jackson's *Black or White*, using their

successful **morphing** technique to cleanly transition from one face to another. The concept had previously been used in videos for The Reels (*Shout and Deliver*)[1] in 1981, and Godley and Creme (*Cry*) in 1985, although the technique used in these two videos was actually analog video dissolves.

Movie 14.10 Black or White (excerpt)



https://www.youtube.com/watch?v=R4kLKv5gtxc

Movie 14.11 Cry

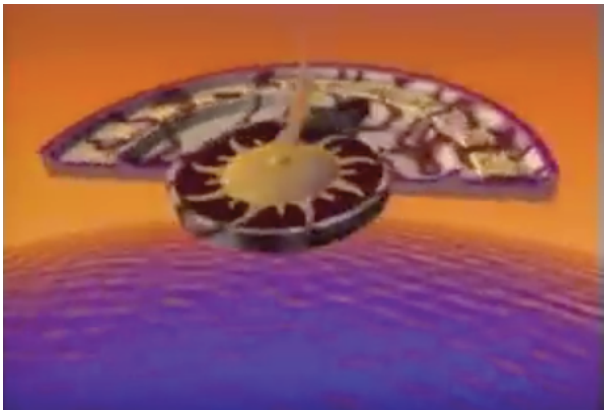


https://www.youtube.com/watch?v=KxtPRF6NG7I

Also in 1991 Todd Rundgren used the Amiga and the Newtek Video Toaster to produce graphics for the video for *Change Myself*. Rundgren produced the graphics in part to show the capabilities of the Toaster.

Movie 14.12 Change Myself

1. Keyboardist Karen Ansel of the Reels left the band and became an animator at ILM, where she worked on the effects for the movie *What Dreams May Come* and other well known movies.



https://www.youtube.com/watch?v=7mH8PaWbi1E
Rundgren talks about how he made the video in a speech at a LA SIGGRAPH 91 meeting at
https://www.youtube.com/watch?v=Jhs24mL8Lx0

Rundgren was active in early music video days, and his video for the song *Time Heals* was one of the first on MTV. He produced a piece for RCA, accompanied by Gustav Holst's *The Planets*, that was used as a demo for their videodisc players.

In the 1990s, Rundgren was a big proponent of the capabilities of the Toaster, and he made several videos with it after *Change Myself*. He also used the system for videos for *Fascist Christ* and *Property* from his album *No World Order*. Later, he set up a company to produce 3D animation using the Toaster, and produced the company's first demo, *Theology*.

Another influential production from Ian Pearson was the 1992 video for Def Leppard for their anthem *Let's Get Rocked* from their album *Adrenalize*. Pearson produced CG effects for a stage in the shape of the British flag, as well as a CG character named Flynn.

Movie 14.13 Def Leppard – Let's Get Rocked



https://www.youtube.com/watch?v=BO1Nae_EBvQ

The German band Rammstein used a combination of CGI and stop-motion to portray an army of ants, mobilized underground by the hero in the video, attacking some foraging beetles in their song Links 2-3-4 (Left 2-3-4). The

video was created in 2001. The video clip referenced here is the "how it was made" video, and is in German with English subtitles.

Movie 14.14 Links 2-3-4



https://www.youtube.com/watch?v=Ddizibd1Et4

The video for Creed's song Bullets is interesting because of its use of video game technology to create the imagery. It was created in 2002 by the team at Vision Scape Interactive. The band was digitized and the imagery created by the game developers included accurate representations of each member, down to their their tattoos. An *article from MTV.com* described the goals:

"It was important that Mark [Tremonti] do battle with an axe because he's a guitar player," added Matt McDonald. "And then Scott Phillips is a drummer, so we gave him two swords. And the designs on the swords came from his tattoos. It was really important to the guys that we matched all their tattoos perfectly. The only thing we did different is we made them a little buffer than they are now."

Movie 14.15 Bullets – excerpt



https://www.youtube.com/watch?v=oPzhUp8mWgs

There have been many more music videos that utilize computer graphics for the visual effects since these early contributions, including videos for Bjork, Coldplay, Shania Twain, Radiohead, Michael Jackson, Gorillaz and others. Wayne Lytle's *Animusic* effort, founded in 1995, is an example of a company fully devoted to videos that

accompany music. In the case of Animusic, the videos are "compilations of computer-generated animations, based on MIDI events processed to simultaneously drive the music and on-screen action, leading to and corresponding to every sound."

The skeleton from Robbie Williams *Rock D.J.* video is particularly noteworthy. The 2000 video showed Williams dancing in a roller rink, trying in vain to get the attention of the D.J. He takes extra steps, stripping off his clothes, then his skin, and finally his muscles so that what remains is a dancing skeleton, controlled with motion capture data. The video was banned in several countries because of the shock value, but won the MTV award for effects that year.

Movie 14.16 Rock D.J.



http://www.dailymotion.com/video/x2rmj_robbie-williams-rock-dj-uncensored_music

A list of the MTV Video Music Award for Best Special Effects ?can be found here.

Todd Rundgren had previously released a software paint package for the Apple II, called the Utopia Graphics System, and with David Levine, the screensaver *Flowfazer – Music for the Eyes*.

Note about some music video ?playback on mobile devices: Some of the music videos referenced in the previous section are not available for playback in their entirety on mobile devices. This could be due to licensing restrictions, advertising on the videos, or the encoding format. If problems arise, try watching on a desktop. Also, many movie and music videos will be deleted from YouTube or other providers if proper clearance hasn't been obtained.

14.3 Tron



The 1982 movie *Tron* was produced by Walt Disney Productions, with CGI by MAGI, Digital Effects, Robert Abel and Associates, and Information International Inc. (III)

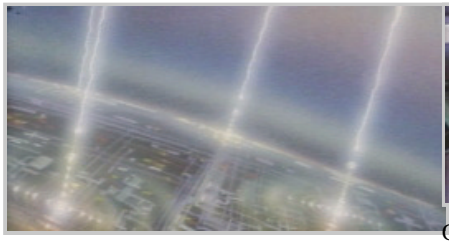
The following text is from a 1982 press release:

> "Walt Disney Productions has combined computer-generated imagery with special techniques in live-action photography that have marked a milestone in optical and light effects. *Tron* brings to life a world where energy lives and breathes, where laws of logic are defied, where an electronic civilization thrives. Starring in *Tron* are Jeff Bridges, David Warner, Bruce Boxleitner, Cindy Morgan and Barnard Hughes. Steven Lisberger makes his feature directorial debut on the film, which he scripted and developed with producer Donald Kushner.
>
> Futuristic industrial designer Syd Mead, comic artist Jean "Moebius" Giraud – whose work is a prime inspiration for the magazine Heavy Metal – and high-tech commercial artist Peter Lloyd served as special visual consultants. Harrison Ellenshaw was associate producer. Special effects were supervised by Ellenshaw and Richard Taylor. Bruce Logan was director of photography.
>
> 
>
> *Steven Lisberger*
>
> Characters in *Tron* are set in landscapes that could not physically exist in the real world, a world where terrains and vehicles are created by computers. Although CGI was used sparingly in movies before (eg, *Westworld*, *Star Trek*, *Looker*) *Tron* was the first motion picture to make such extensive use of computer imagery.
>
> *Tron* completed principal photography in July, 1981. Post-production continued through the spring of 1982 for a summer 1982 release by Buena Vista, in color by Technicolor. Filmed in Super Panavision 70."

Tron is set in two worlds: the real world, where a vast computer system in a communications conglomerate is controlled by a single program; and the electronic world, whose electric-and-light beings want to overthrow the program which controls their lives. The electronic world was shot on sound stages at Walt Disney Studio in Burbank. Photography for the real world took place at locations around Los Angeles, and at the U.S. Government's Lawrence Livermore Laboratory outside Oakland, California.

Computer graphics were first applied to aerospace and scientific research in the mid-1960s, when methods of simulating objects digitally in their dimensions proved as effective as building models. The technology was then diverted into the entertainment field. Information International Inc. (Triple-I) and Robert Abel & Associates of Los Angeles, and the Mathematic Applications Group Inc. (MAGI) and Digital Effects of New York – four of the nation's foremost computer graphics houses – produced the computer imagery for *Tron*.

Computer-generated landscapes, buildings and vehicles provided settings for live-action characters in the film's electronic world. MAGI, the single largest contributor of computer imagery, speeded the process of supplying its work to Disney Studios in Burbank by a trans-continental computer hook-up. Before each scene was finalized in MAGI's lab in Elmsford, N.Y., it was previewed on a computer monitor at Disney. Corrections could then be made in the scene immediately. Previously, the only way of previewing the scene was to film it, ship it to Burbank, get corrections made, ship it back to Elmsford… and continue this ping-ponging until the scene was correct. The computer link cut between two-and-a-half to five days from the creation of each scene.



Vistas

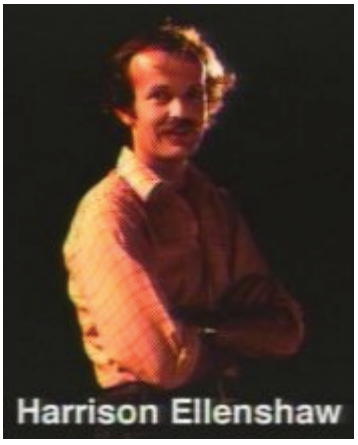


Canyons



Balls

Tron was not a box office success, for several reasons. One big reason is that its release, originally scheduled for Spring of 1982, was delayed until summer. It therefore competed with several other major films, including *ET: The Extraterrestrial, Blade Runner, Fast Times at Ridgemont High, Poltergeist, Friday the 13th (Part 3), and Star Trek II The Wrath of Khan* (and, of course, *Porky's*). Also, the 15 minutes of CGI and the over 50 minutes of backlit animation drove the cost of the movie to over $20M.



Ellenshaw

Harrison Ellenshaw was associate producer and co-supervisor of special effects. After earning a degree in psychology from Whittier College in 1964, Ellenshaw turned to art and apprenticed in the matte department at Disney Studios. Within 10 years he was considered one of the top matte artists in the film business. Ellenshaw has painted mattes for T*he Man who Fell to Earth*, *Star Wars*, *The Black Hole*, and was part of the team which won the optical effects Oscar for *The Empire Strikes Back.*



Richard Taylor

Richard Taylor, who headed the Entertainment Technology Group at Information International Inc., was co-supervising the special effects on *Tron.* He oversaw the design and programming of the film's computer animation. After stints in the Naval Academy, the Merchant Marines and as a Wyoming ranch hand, Taylor earned a graduate degree in art and film from the University of Utah in 1969. He then co-founded Rainbow Jam, a company which designed computerized light shows for rock concerts. In 1973 Taylor joined Robert Abel and Associates in Los Angeles, where he designed graphics for television commercials. In 1979 he moved to Information International. He was assisted at MAGI by Larry Elin, head of MAGI's computer graphics division, and by optical effects artist John Scheele.

The production of *Tron* marked the first time that computer-generated imagery (CGI) had been extensively used in a feature film. A full fifteen minutes of the film consists of moving images generated entirely by computer. Additionally, there are over two hundred scenes that utilize computer-generated backgrounds. Much of the remaining effects in the film were backlit optical effects. Because of the amount of the computer-generated imagery necessary for *Tron*, the filmmakers decided to divide the work among four different companies that specialized in computer graphics: Digital Effects, Robert Abel & Associates, Mathematical Applications Group Incorporated (MAGI), and Information International Incorporated (Triple-I).

In the paragraphs below, Computer Effects Supervisor Richard Taylor and Computer Image Choreographer Bill Kroyer discuss the challenges of using computer generated imagery for the film:

> **Taylor:** "I think the most difficult thing in doing *Tron* was to marry the computer simulation moments with the live-action photography, and have them feel like they were all in the same place. The fact that we were shooting people in black and white costumes on sets that were black, and matting those people into computer simulated worlds, and that many of those backgrounds were computer simulated scenes putting people in them or computer simulated images into graphically created scenes and matting people into that; to have that all homogenize and feel like it is the same place so you don't say 'that was done that way and this was done this way.' And also that all the work done by MAGI, Triple-I, Abel all married and felt like one thing, so you wouldn't say, 'Oh, that was done by MAGI, that was done by Triple-I,' so that it just became a homogenized world where it all melted together. As a design problem and as a film-making problem, I think that was the most difficult thing to do. It was what I was most pleased with that it did work so well. I noticed very early on in my work with computer simulation that all the different companies who did it basically had their own technique for doing it. It's like they each had their own kind of hot rod, and their own kind of crew, and they were all hybrid systems. The most difficult thing was getting them to have the same vocabulary, same understanding, same description of three space motion, same description of a color.
>
> After looking at it for a while, I realized that there were similarities that everybody understood. Basically, it's everybody's understanding of three space, of dimensional choreography, how surfaces are rendered, whether one company could make things shiny or smoother or more like chrome; that's basically when you get down to making a picture a matter of art direction."
>
> **Kroyer:** "When we started dealing with the computer companies on *Tron*, you have to remember that a lot

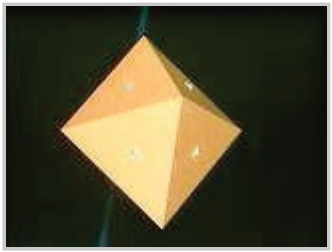
of the people developing software for computers are not really film-makers. The didn't begin their career as film-makers. So they won't approach the creation of visual imagery the same way that a film-maker will. We went in not knowing anything about computer technology. We only knew what we wanted to achieve on the film. With discussions with the development groups of each company, we were convinced that we could actually develop the technology as we went along and marry it with the creative needs, and end up with a film that would look good. As an example, we wanted a feeling of vast scale in *Tron*. We wanted that cycle arena to feel like it was miles wide. When a computer creates a picture, it will create everything crystal clear. So something that's a mile away will actually appear as clear and distinct and as well lit as something that's a foot away. That just doesn't look real. So we said that we need a feeling of atmosphere in these shots. We have to make it look as though things that are far away are far away. In real life you do that by softening the focus, and kind of dimming the colors.

We came up with something that is very simple and I think is standard technique now in computer graphics which is called depth glowing. You assign a mathematical progression to the light of the points, depending how far away they are from the camera source. The farther away they are the less distinct they are, and that makes them look farther away. It's something you automatically get in live-action photography. It's something you have to mathematically apply to a computer image. Again, it was this constant give and take with our visual requirements with their technical possibilities that created *Tron*. When we finished Tron, we had pushed the technology of these companies I think many, many years ahead of where they would have been if they hadn't worked with us during the feature."

Digital Effects, Incorporated, animated the Bit character and the creation of the *Tron* character in the opening title sequence.

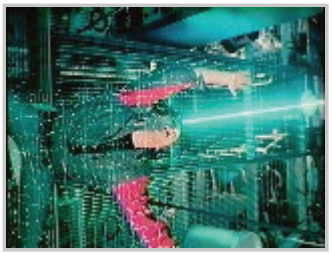


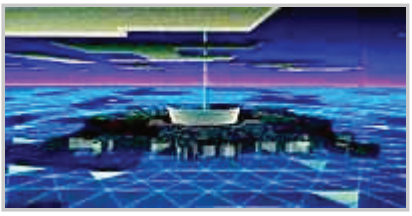
The Bit character from TRON – ?No state



The Bit character from TRON – ?Yes state

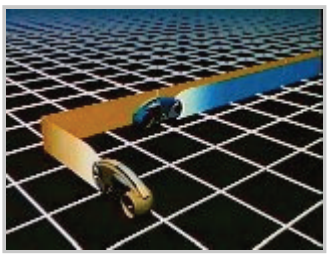
Robert Abel & Associates provided the remaining animation for the opening sequence and for Flynn's transition into the Electronic World.





Because of their abilities to create complex motion and 3-D shaded graphics, the bulk of the computer animation was handled by MAGI and Triple-I. MAGI's computer imagery occurs mostly in the first half of *Tron* in the Game Grid area, where they created such vehicles as the Lightcycles, Recognizers and Tanks.









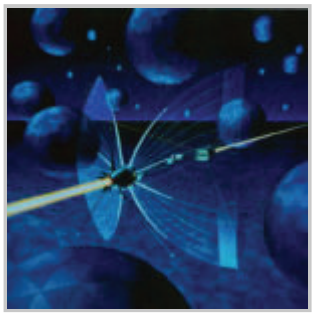
MAGI employed a unique process of computer simulation call SynthaVision. This process utilized basic geometric shapes that the computer recognized as solid objects with density. By varying the size and quantity of these shapes, MAGI could construct a limited variety of three-dimensional designs and animate them easily. The SynthaVision process was limited in its ability to create complex objects. It was, however, very easy to create fluid motion (choreography) for these objects. Based on its strengths in motion animation, MAGI was assigned the computer imagery for the first half of the film, which consists mostly of dynamic action sequences.

The following are transcribed interviews from excerpts of a TV special entitled "*Beyond Tron*," which explores MAGI's involvement in *Tron*.

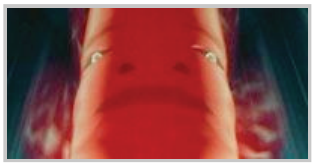
> **Dr. Phillip Mittelman, Founder of MAGI:** "When MAGI was first started in 1966, we were working primarily with the government doing what's called nuclear radiation transport. Worrying about, if you had a nuclear reactor, how much radiation would come out and what kind of radiation dose would people get. The way we did that was to describe three dimensional objects, and then follow around the nuclear radiation, follow it through its path through the material. One day we realized that if we followed light rays instead of nuclear radiation, we could simulate photography. We could simulate following the light rays from the sun to the object, from the object in through the camera lens to the film. If we could just calculate how much light hit each point on the film, we could make a photograph of things."
>
> General MAGI information From The Special: In 1967, the Mathematics Application Group, Incorporated turned their efforts to developing a program to create movies in the computer. They added color and other refinements to the software, and in 1972, MAGI SynthaVision introduced the process to the advertising world. The program has been refined over the years, but is still unique in the industry. Rather than use just polygons as the beginning point for the animation, MAGI SynthaVision uses combinations of other kinds of shapes to describe objects and to bring texture and contours to the surface. In 1975, a young animator from Boston was present at a screening conducted by Phillip Mittelman of the computer graphics his company had been creating for advertisers and other clients. The future writer/director of *Tron*, Steven Lisberger, was fascinated with the computer's ability to conquer perspective and lend a 3D feeling to images.
>
> **Steven Lisberger:** "I think on that original reel from MAGI, the thing that stuck with me the most, that I couldn't get out of my head for years, was the image of moving through a computer generated environment.

> When a year or two after that, the video games started becoming popular, and I started talking to the computer people, it seemed that I now had the characters I could put into that computer environment."

The computer imagery seen in the second half of the film, such as the MCP and the Solar Sailer, is the work of Triple-I.



Solar Sailer





MCP



Sark's Carrier



These images are among the most complex designs in the film. Unlike MAGI's SynthaVision process, most computer graphics companies today employ a method similar to that used by ?Triple-I. Using a schematic drawing or blueprint, Triple-I engineers recorded the visual images by tracing the lines of a drawing onto a digitizing tablet. This information was translated ??to the computer as an image whose surface is composed of a multitude of polygons (i.e., triangles). At a 1981 convention for computer graphics (SIGGRAPH), Triple-I presented a demonstration ??reel that illustrated the company's achievements in computer imagery. This reel was instrumental in convincing the Disney Studios' executives that computer animation could be successfully integrated into a motion picture.

Richard Taylor discusses the role that the Triple-I demo reel played in Disney's decision to make *Tron*:

> ?"The conference saw a big 35mm representation of what really had a beginning, middle, and an end. It tried to really demonstrate to the world the potential of this medium. It had a great effect. It helped other people develop their things. It gave them an insight into what you could really do. And it had everything to do with why Disney believed that *Tron* could be done. Because it was a piece of film that they could see that worked overall and had a wide range of things that had been choreographed and created specifically."

Tron began as the inspiration of Writer-Director Steven Lisberger. In the mid-seventies, Steven Lisberger was operating a studio in Boston that was producing animation for commercials and for the title sequences of television programs. At that time, he began exploring the possibilities of using computer-generated imagery for a story about characters that lived inside a video game. Using conventional animation, Lisberger produced this animated logo for his studio, which was licensed as advertising to several radio stations around the country. This was the first appearance of a character that he called *Tron*. As originally conceived, *Tron* was to be predominantly a traditional animated film. The story would begin with live action to portray the Real World. Later, the Electronic

World inside the computer would be represented by a combination of computer-generated imagery and hand-drawn, backlit animation.

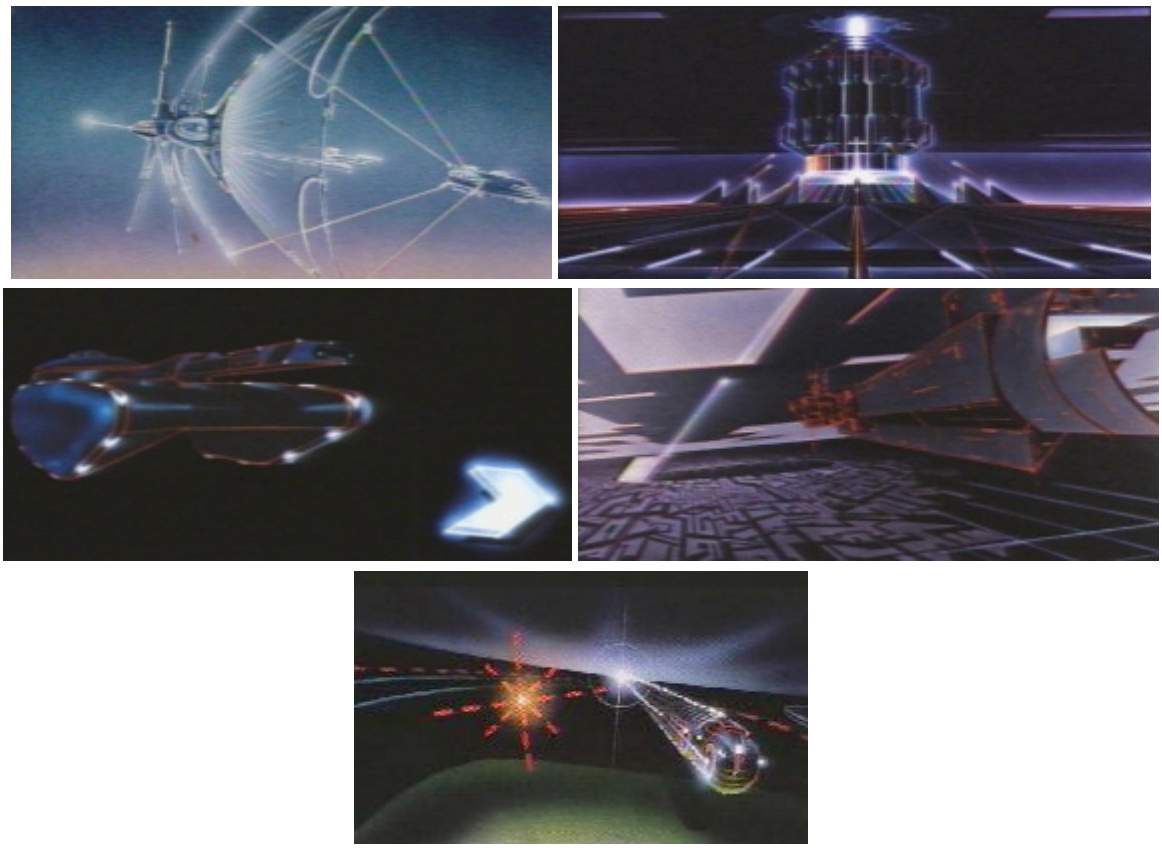
In 1977, Lisberger partnered with attorney and theatrical producer Donald Kushner to produce an animated spoof of the Olympic Games entitled "*Animalympics*." Lisberger and Kushner moved their studio (along with eighteen artists) to Venice, California, in 1978. Their hope was to finance *Tron* independently with the revenues from this film. Unfortunately, the U.S. boycotted the 1980 summer Olympics, and "*Animalympics*" was not as lucrative as it otherwise might have been. Lisberger and Kushner were forced to seek studio backing for *Tron*. In June, 1980, they approached The Walt Disney Studios with a detailed proposal for the project. Their ideas were enthusiastically received, and pre-production began shortly thereafter. Steven Lisberger and Donald Kushner discuss the early stages of development and inspirations for *Tron*:

Lisberger: "When I wrote the script for *Tron*, it was my intention that the film would be done by computer generated imagery, because you could only tell the story with computer generated imagery. It wasn't a question of a choice where one would say, 'well, we can do it this way, we can do it that way.' I was inspired by the film Star Wars, not just in a specific sense of effects. I was inspired by that film, I guess it came out in the late 70's. I was inspired by that. I was inspired by Jaws. Just because it seemed up to that point in time that films were becoming very formula oriented. When those two films in particular came out, it seemed that they had so much energy and so much excitement, and that they were willing to try new techniques in ways that would aid their stories and cinematically make certain things possible. Those films definitely had some bearing on making me feel that a film like *Tron* would be possible or could get made."

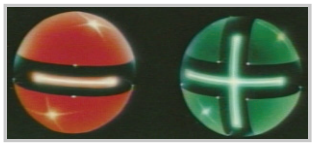
> **Kushner**: "One of the difficult areas on *Tron* was to create a unified look for both the real world and the electronic world. Like in *The Wizard Of Oz*, there are two worlds. The difficult part was integrating both of the worlds. We used computer simulation, we used backlit techniques, and we used conventional live action. The difficult part was to make them all part of a cohesive look in this film. In that respect, I think we achieved our goal, of creating an overall unified look. When we started marketing the picture to studios, Disney was one of the last on the list. The reason is that since they were the vanguard of traditional animation, that they probably would not be interested in computer simulation. Or if they were interested in computer simulation, they would probably want to develop something in house. As it turned out, when we presented the project to them, they were very susceptible from the very beginning. So it turned out that it was very easy to persuade them since this was an area that they had been looking for and were exploring how to get involved in. We presented them with a project that was ready to go."

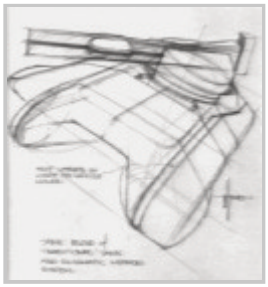
Soon after Disney committed to the project, conceptual artist Andy Probert (who later would go on to create designs for the television series "*Star Trek: The Next Generation*") was brought on to create designs of vehicles, sets and costumes. However, none of his designs were used in the final film. In early 1981, Steven Lisberger assembled an illustrious team of artists to finalize the designs for *Tron*. This team included Jean "Moebius" Giraud, Syd Mead and Peter Lloyd. Moebius, a French comic book artist known for his work in the magazine "Heavy Metal," contributed costume designs and storyboard art. The designs of the vehicles and computer environments fell to futuristic industrial and film designer Syd Mead. Commercial airbrush artist Peter Lloyd designed environments and backgrounds, in addition to serving as a color stylist.

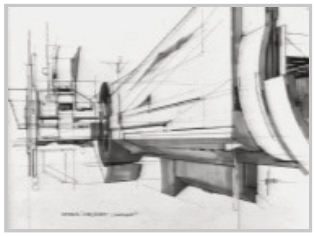
Gallery 14.1 Peter Lloyd Designs

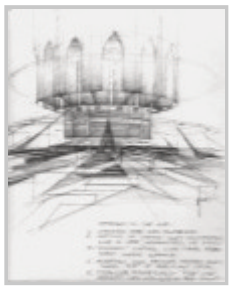


Gallery 14.2 Syd Mead Designs

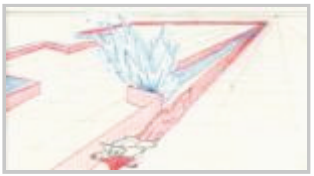
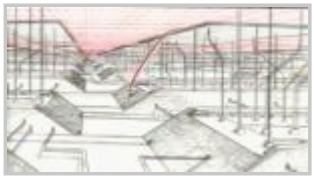









Gallery 14.3 Moebius storyboard art

See also *http://www.tron-sector.com*/

Movie 14.17 Tron Trailer



Original trailer for the movie Tron from 1982.
https://www.youtube.com/watch?v=3efV2wqEjEY

14.4 Miscellaneous



The July 2002 issue of *Computer Graphics World* featured Part 7 of their retrospective series, devoted to coverage of CG in the movies, written by Barbara Robertson. A copy of this feature is included on their web site at

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/05/CGWRetrospective-Part7.pdf

The first Academy of Motion Pictures Arts and Sciences award for science and engineering or technical achievement was given in 1984 to John Whitney Jr. and Gary Demos of Digital Productions. After a lull in these awards, they began recognizing the contributions of the CG industry again in 1991, and since then many of the individuals and companies that have contributed to the motion picture industry have received their just recognitions.



Gary Demos, right, winner of the Gordon E. Sawyer Award, an Oscar statuette, is pictured here with actress Rachel McAdams, host of the Academy of Motion Picture Arts and Sciences' Scientific and Technical Awards Ceremony on February 18, 2006, at The Beverly Hilton in Beverly Hills, CA.

Issac Kerlow has a timeline of animation and visual effects in his book *The Art of 3D Computer Animation Effects*. A digital capture can be found at *Google book's site*

AMC Filmsite has a listing of visual effects in the movies at

http://www.filmsite.org/visualeffects.html

A list of the Academy Awards for Best Visual Effects can be found at

https://en.wikipedia.org/wiki/Academy_Award_for_Best_Visual_Effects

Note: The reference for the table below is unknown at this time.

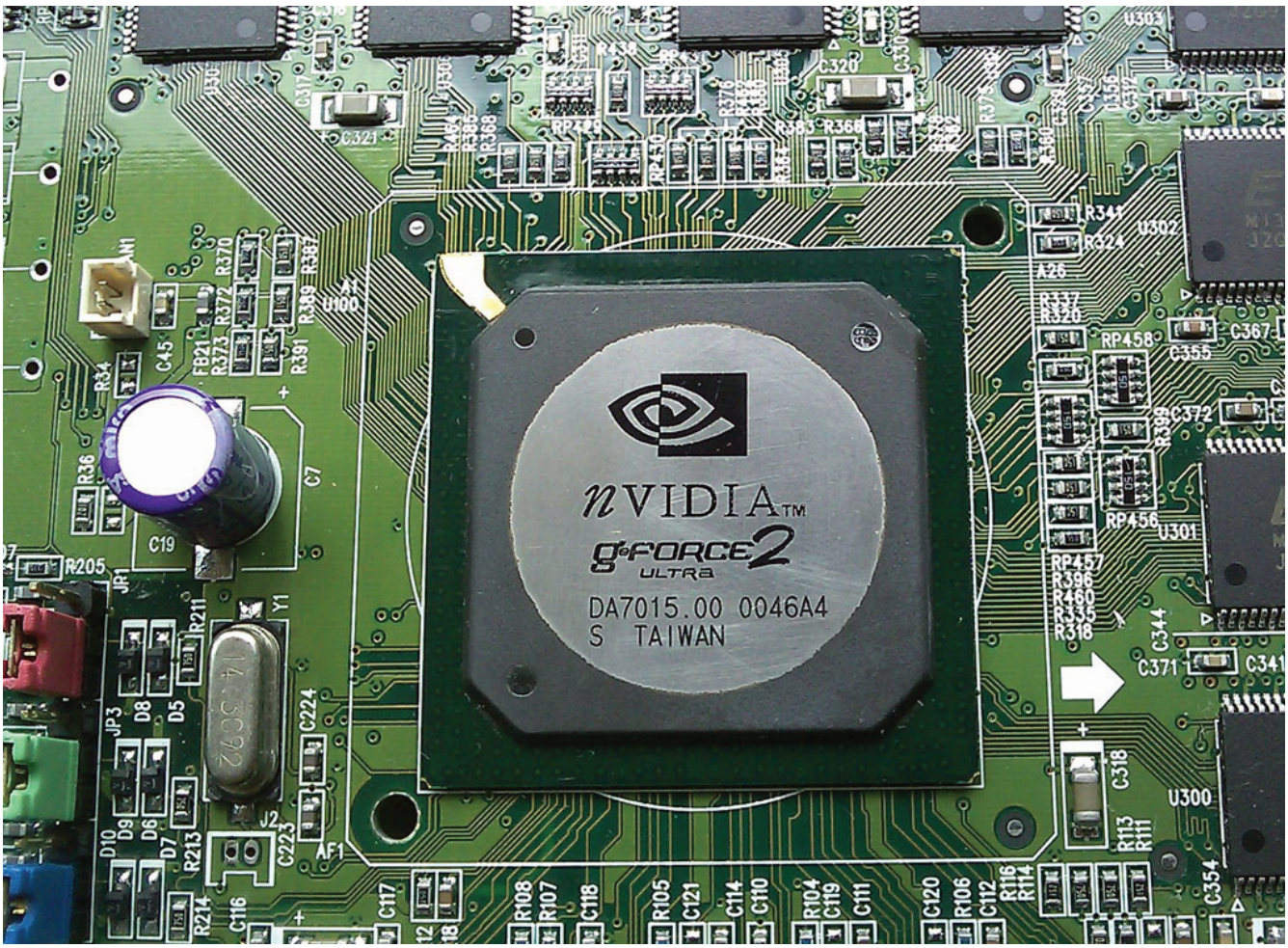
It's hard to believe that the first real use of what we now know as CGI in a feature film was in 1973, when we were treated to the computerized point of view of Yul Bryner's robot gunslinger as he ran amok in *Westworld*. But it would be another 20 years before Hollywood experienced a real revolution in special effects, when, in a nice coincidence, photorealistic dinosaurs rampaged through *Jurassic Park*, another Michael Crichton-inspired theme-park-gone-wrong movie. Here are some landmarks in the history of CGI in films.

FIRST…	FILM
Use of 2-D computerized images	*Westworld* (1973)
Use of 3-D computer graphics	*Futureworld* (1976)
Use of animated 3-D wire-frame graphics	*Star Wars* (1977)
Use of shaded 3-D CGI	*Looker* (1981)
Film to feature extensive CGI (over 20 minutes)*	*Tron* (1982)
Use of 'integrated CGI' to represent real-world objects	*The Last Starfighter* (1984)
Disney animated film to contain CG objects	*The Black Cauldron* (1985)
Photorealistic CG character	*Young Sherlock Holmes* (1985)
Use of photorealistic morphing effects in a feature film	*Willow* (1988)
3-D CG water effect	*The Abyss* (1989)
CG character with realistic human movements	*Terminator 2: Judgement Day* (1991)
Photorealistic CG creatures	*Jurassic Park* (1993)
CG characters to interact realistically with live actors	*Casper* (1995)
Full-length CG animated film	*Toy Story* (1995)
Full-length CG film based on photorealistic and live-action principles	*Final Fantasy: The Spirits Within* (2001)*

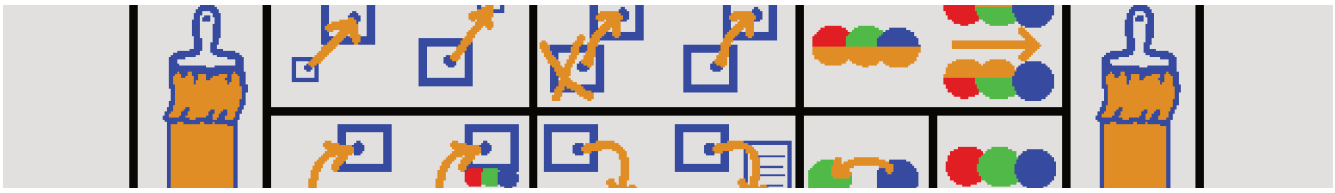
Chapter 15: Graphics Hardware Advancements

Graphics Hardware Advancements

As the computer workstation was developed, graphics algorithms were accelerated by embedding the logic in the display hardware, and the Graphics Processing Unit, or GPU, made real time graphics a possibility.



15.1 Early Hardware



For a little more than a decade in the beginning of computer graphics history, images were created and displayed as vectors – straight lines connecting points on the screen of a CRT. These displays were “refreshed” from a display list, which was a portion of memory that the display controller accessed to determine what to draw. A change in the image was accomplished by a change in the contents of the display list, which could be done fairly rapidly.

The “democratization of computer graphics”, as one author put it, was made possible by the introduction of raster graphics. This technology used a standard television CRT that utilized a video controller to scan the image from top to bottom, turning on or off the individual addressable points on the screen, and providing information as to the color of the points. The video controller obtained its information from a memory array whose contents represented in a one-to-one match the points on the screen. This memory was called a frame buffer, and was significantly larger than the display list memory of vector devices. Each point on a line in a raster system had to be stored, not just the endpoints of the line required by the vector displays. An early standard TV had approximately 250,000 addressable points (called pixels) on the screen, so the memory was rather large, particularly when color was included (which increased the size by a factor of three.)

As was mentioned earlier, core memory was the technology until the 1960s. There were some early implementations of a frame buffer comprised of core arrays, but they were bulky and expensive. The first breakthrough in affordable memory technology came with the introduction of integrated circuits. At this point, some experimental “shift-register” frame buffers were introduced. Each location on the screen was represented in the shift register as a bit. A refresh cycle for a scan line on the raster device was accomplished by shifting all the bits in the register and reading the one on the end, placing it at the beginning and shifting the bits again. The intensity of a screen element could only be changed when its bit came up at the end of the register. This resulted in a delay for screen updates.

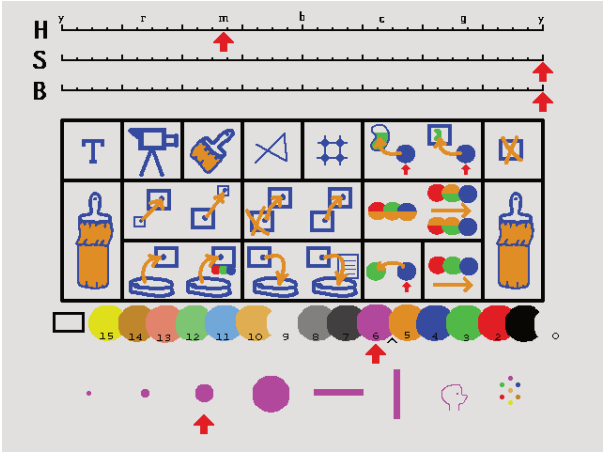
The real contribution came with the introduction of the **Random Access Memory** (RAM) chip a few years later. Instead of the sequential storage required in the shift register, the RAM allowed the computer or display processor to access any bit at any time – randomly. A 1K (1024) bit RAM chip was available in 1970, allowing for the

affordable construction of a frame buffer that could hold all of the screen data for a TV image, and it could be updated rapidly because of the access capabilities for each bit. In order to increase the complexity and realism of the image on the screen, even larger frame buffers allowed displays as large as 1024×1024. The depth (the number of bits used to represent the intensity and color of each pixel) increased from 1 to 8 to accommodate color, and then to 24 (8 bits for each RGB value) and upwards.

Because of the cost of the frame buffer at this time, a user who needed the image complexity of the 24 bit version had to look for other approaches. (24-bit color is sometimes referred to as “true” color. With 256 levels of red, green and blue a total palette of 16.7 million colors is possible.) One approach was to use an 8 bit frame buffer and the “look-up table”.

In an 8 bit buffer, 8 bits of data represented all the information for a pixel. A normal configuration would allow 3 bits each for the Red and Green color channels, and 2 for Blue. Thus Red and Green could achieve 8 levels each (2x2x2), and Blue had 4 levels (2×2). Hence one could represent a total palette of 256 colors, which is barely capable of representing realistic color. Better realism was achieved through the use of an “adaptive” palette of colors. In this case the image is analyzed and the best fit of 256 colors is directed to a look-up-table (LUT) where each color is associated with an 8-bit address in the table. So rather than representing the intensity/color directly with the 8-bit element of the frame buffer, the location of the intensity/color stored in the table was recorded as an 8-bit address in the frame buffer. To refresh the screen, the address was read from the frame buffer, the processor then pulled the intensity value from the table at that address, and refreshed the image accordingly.

Still, early frame buffer designs were constrained by the high bandwidth required to refresh the entire screen. Software and hardware modifications made this less of an issue, with implementations like the **Bit BLT** (block transfer of bits) operator that allowed larger portions of the image to be updated as a unit, and word organizations in which the buffer was organized into words that contained multiple pixels. Later, the frame buffers were enhanced with hardware; the z-buffer was introduced by Catmull in 1974, hardware implementations of which included RAM to represent not only the RGB colors for each pixel, but also the z depth from the 3D geometry to be used for update comparisons. Hardware, such as the enhanced frame buffer described by Whitted, was added to the memory to perform operations such as the z-comparison separate from the CPU.

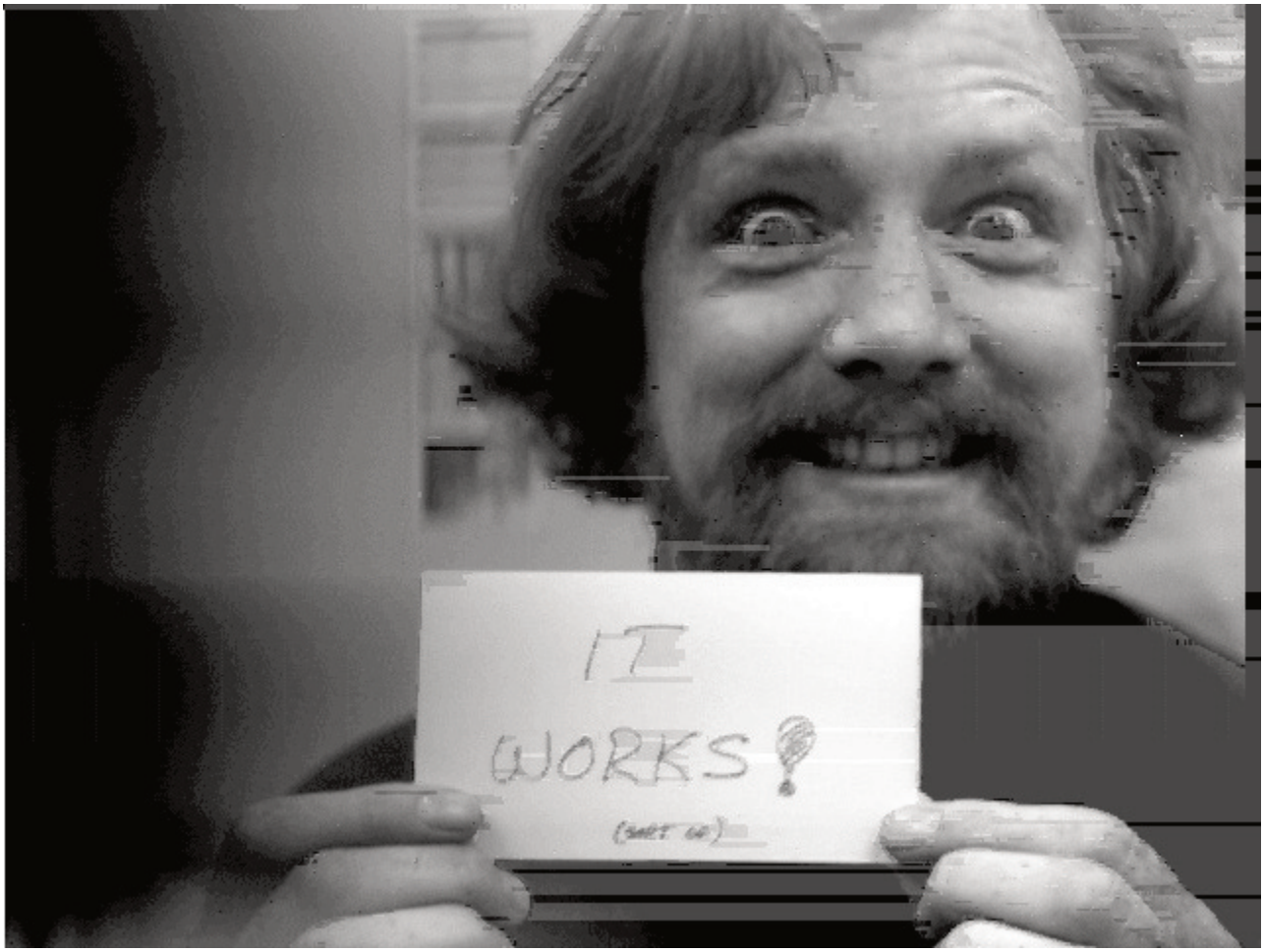


Superpaint Menu Screen

The frame buffer was developed and expanded in both commercial and proprietary environments from the late 1960s through the early 1980s. Bell Labs developed a 3-bit system in 1969; Dick Shoup developed an 8 bit frame buffer at Xerox PARC for the *SuperPaint* system (Shoup later founded Aurora Systems); NYIT developed the first 24 bit RGB buffers; a flexible system was designed at North Carolina State University, and later modified at Ohio State; companies like Evans and Sutherland, Genisco and Raster Tech developed commercial versions; the NCSU buffer evolved into a commercial programmable display developed by Nick England called the *Ikonas* system, which later became the

Adage system. In 1984, Loren Carpenter introduced the **alpha channel** to the frame buffer, allowing images to be efficiently composited with **antialiasing**.

Most installations used the same workflow configuration during this time: a mainframe computer or minicomputer was accessed by multiple users, each with a terminal but sharing a frame buffer, which was connected to the computer with a Bus interface. The concept of the single user workstation, configured with its own internal frame buffer was still on the horizon.



"This is the very first picture captured in the SuperPaint frame buffer when it first came to life in April, 1973. The system took a standard video signal as input, digitized it to 8 bits, and could capture or combine it with other data. To take this picture, I pulled a clip lead off of the back panel using my knees. The card says 'It works! (sort of)'. At this moment the interface to the Nova 800 CPU had not been debugged or even plugged in to the system yet. In order to preserve this picture, I had to plug the interface card in and get it working with the power on. Later, I was able to clean up some of the missing bits with a heuristic program and some fiddling." ??(Dick Shoup, quoted in Alvy Ray Smith: RGBA, the birth of compositing & the founding of Pixar, by Mike Seymour at fxguide.com)

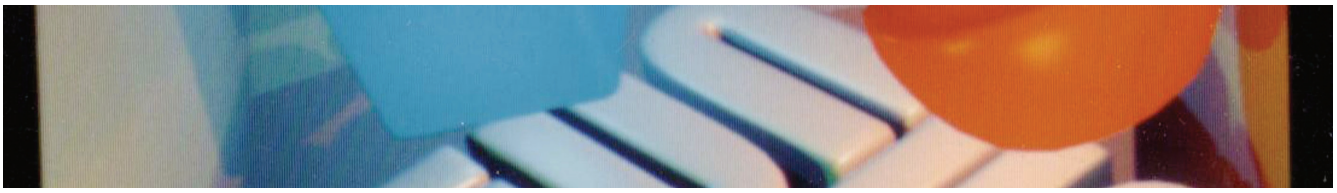
Catmull, Ed. *A Subdivision Algorithm for Computer Display of Curved Surfaces*, Ph.D. Thesis, Report UTEC-CSc-74-133, Computer Science Department, University of Utah, Salt Lake City, UT, 1974

Whitted, Turner, “Hardware Enhanced 3-D Raster Display System,” Proceedings of the 7th Man-Computer Communications Conference, 1981.

Fuchs, Henry. Distributing A Visible Surface Algorithm Over Multiple Processors. Proceedings of the ACM National Conference 1977

For a discussion of paint systems and the development of hardware support, see Alvy Ray Smith’s article *Digital Paint Systems: An Anecdotal and Historical Overview*, from the April 2001 issue of the IEEE Annals of the History of Computing

15.2 Apollo / SGI / Sun



In the early 1980s some computer companies concentrated their efforts on the development of specialized workstations, the "**graphics workstation**". Customers used graphics workstations for electronic and mechanical design because basic workstations were too slow and lacked sophisticated graphics.

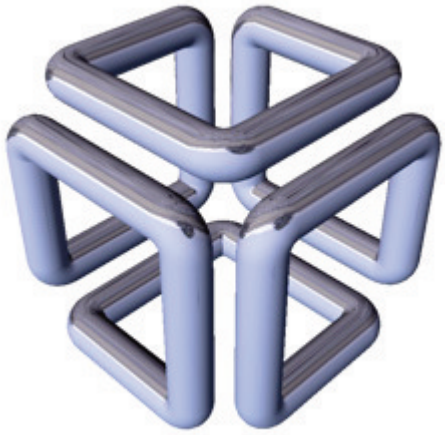
Apollo

Several early graphics workstations were sold by Apollo and Sun. Early on the Sun 1, the Sun 2 and Sun 3 workstations came on the market. Apollo, one of the real workstation pioneers, started their workstation development in 1981 with the DN100 and later the DN550. Their workstations were widely used through the mid 80s, and Apollo, Sun, and HP each had about 20% of the workstation market when Apollo (after a short try at a joint project with Intel), produced the DN3000, the DN4000 and four-CPU DN10000 workstations (DN meant "DOMAIN Node".) They introduced the PRISM CPU to the market. It was the first real two-instruction microprocessor and the fastest available workstation until the IBM RS/6000 series. Apollo was acquired by HP in 1989, and they merged their own Series 9000 workstation line with that of the Apollo systems.



© Apollo Computer

SGI



3D representation of the SGI mark

One of the most important contributions in the area of display hardware is attributed to Jim Clark of Stanford in 1982. His idea, called the Geometry Engine, was to create a collection of components in a **VLSI** processor that would accomplish the main operations that were required in the image synthesis pipeline: matrix transforms, clipping, and the scaling operations that provided the transformation to view space. Clark attempted to shop his design around to computer companies, and finding no takers, he and colleagues at Stanford started their own company, Silicon Graphics Inc.

Silicon Graphics Inc. (later known simply as SGI) was one of the leading manufacturers of graphics computer systems, workstations, and supercomputers. Its history may be described as an exemplary Silicon Valley success story, until lower-priced competitors and inept production methods resulted in heavy losses in the late 1990s. Silicon Graphics capitalized on pioneering technology in 3-D computer graphics to create products used in a wide variety of professions, including engineering, chemistry, and film production.

In 1983 the company released its first products: the IRIS (Integrated Raster Imaging System) 1000 graphics terminal and an accompanying software interface known as the IRIS Graphics Library. It used the 8MHz M68000 processor with up to 2 MB memory, a custom 1024×1024 frame buffer, and the Geometry Engine gave the workstation its impressive image generation power. The next year Silicon Graphics released its first workstation, the IRIS 1400, and followed it in 1985 with the IRIS 2400, a workstation with a window manager. These early

entries in the IRIS series targeted the middle range of the graphics workstations market – those selling for $45,000 to $100,000 – and accounted for over 50 percent of all 3-D graphics workstations sold by 1988.

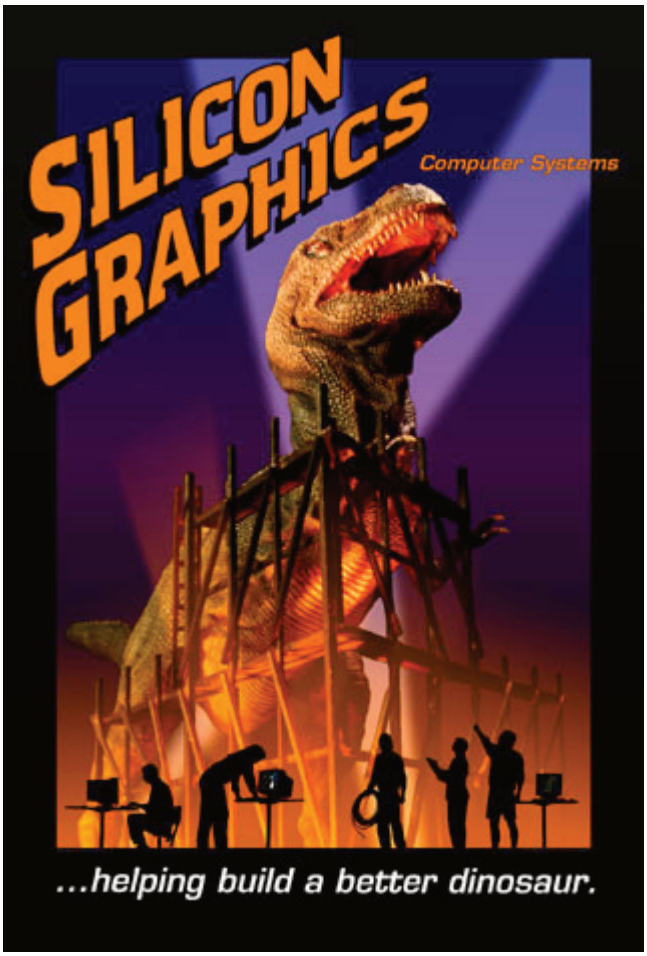
Silicon Graphics succeeded because it introduced a product that served cross-markets, from 3-D graphics simulations useful to mechanical engineers who wanted to assess their designs without having to build prototypes, to chemists who used 3-D modeling to study molecules. Such workstations as the IRIS series provided power at a relatively affordable price and major workstation manufacturers, including Hewlett-Packard, Apollo Computer, and Sun Microsystems, were slow to focus their energies on 3-D graphics, leaving Silicon Graphics without much direct competition.

In 1987 it became the first computer company to make use of MIPS Computer Systems' innovative reduced instruction-set chip, or **RISC**, when it incorporated RISC architecture into its new IRIS 4D/60 workstation. Within several years, most workstations would use RISCs. The company received a boost the next year when IBM agreed to buy Silicon Graphics' IRIS graphics card for use in its own RS/6000 graphics workstations and to take out a license for the IRIS Graphics Library, helping to make the IRIS Graphics Library the industry standard.

Also in 1988, Silicon Graphics introduced a new line of entry level graphics workstations, which it called Eclipse. The Eclipse was designed to bring 3-D graphics to people who had previously regarded IRIS workstations as unaffordable. Eclipse lacked the speed and processing power of more expensive machines, but initial versions sold for less than $20,000 – as little as one-fifth of the cost of higher-end machines.

In 1991 the company released an even less expensive product line – the IRIS Indigo, a 3-D graphics workstation so compact that the company called it the first personal computer to use RISC architecture. The Indigo offered many features found on more expensive models, as well as digital audio and video processing capability, and the base model sold for less than $10,000.

In 1991 the company granted a license to Microsoft for the IRIS Graphics Library. Microsoft intended to use the IRIS Graphics Library in its NT operating system for personal computers.



SGI Jurassic Park Poster

In 1993 Silicon Graphics and Industrial Light and Magic joined forces to create a high-tech entertainment special effects laboratory. The joint venture was called Joint Environment for Digital Imaging (JEDI) and grew out of the fact that Industrial Light and Magic had been using Silicon Graphics workstations since 1987. The cyborg featured in the film *Terminator 2*, the dinosaurs in *Jurassic Park*, special effects in *The Hunt for Red October* and *The Abyss*, and animation in *Beauty and the Beast* were all created on Silicon Graphics computers. For Industrial Light and Magic, the benefits were that digital manipulation of images cost about one-tenth as much as models and drawings, and, according to Lucas, would "change motion pictures from a photographic process to more of a painterly process," enabling greater authorial control over a film's appearance. For its part, Silicon Graphics hoped that alliance with an entertainment industry partner would help push the leading edge of its technological development forward.

In 1995 Silicon Graphics teamed up with DreamWorks SKG – the entertainment entity formed by Steven Spielberg, Jeffrey Katzenberg, and David Geffen, and DreamWorks Digital Studio for the creation of animation, feature films, and other products. Silicon Graphics also acquired Alias Research and Wavefront Technologies for $500 million in 1995, which positioned Silicon Graphics in the software business. Alias specialized in ?3-D animation software that was widely used in the entertainment industry and in industrial design. It had developed new ways to simulate wind, fire, skin, and other special effects, and it also had an animation tool used by Nintendo in its video games. WaveFront Technologies developed industrial visualization software.



SGI "Impact" Poster

In April 1999 Silicon Graphics Inc. changed its name to SGI as part of a new worldwide corporate identity strategy that reflected the breadth and depth of the company's products and services. The strategy included three sub-brands: SGI servers and workstations, Silicon Graphics visual workstations, and Cray supercomputers.

(Note: In 2005, SGI was delisted from the NYSE and filed Chapter 11 in 2006. They reemerged from bankruptcy later that year, but were delisted from NASDAQ in 2008. They again declared bankruptcy, and sold their assets to Rackable Systems in 2009 for $42.5M. Their downfall was documented in an interesting series of web articles at http://www.vizworld.com/tag/sgi-bts//)

Sun

At about the same time in 1982, Sun Microcomputers was founded. They also introduced a workstation that had an embedded frame buffer. The CG1, CG2 and CG3 boards were the boards used in the Sun 1, Sun 2 and Sun 3 workstations. (The Apollo workstation also provided the single user-dedicated frame buffer technology.) Sun later used an add-on accelerator board made by *Trancept Systems* for the Sun 3 and Sun 4 workstations.

According to Nick England, one of the designers of the TAAC board:

> In the Spring of 1987 we introduced the TAAC-1 product for Sun Microsystems workstations. The TAAC-1 consisted of two large PC boards, one full of video RAM, the other full of a micro-programmed wide-instruction-word (200 bits) processor optimized for graphics and imaging operations. The TAAC-1 was plugged into and memory mapped onto the Sun's VME bus.

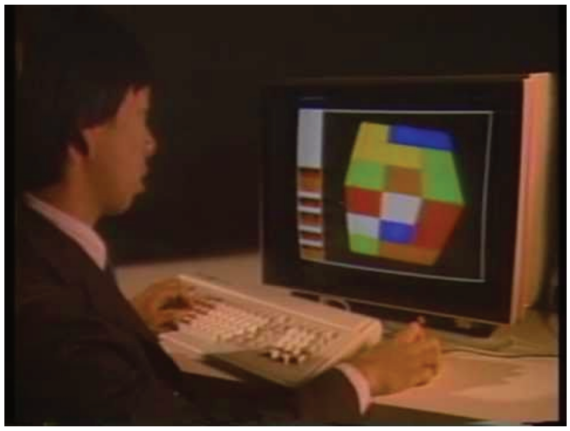


Trancept Systems Poster

The Trancept board was intended to be replaced by the VX/VMX boards in 1990. The VX included one Intel i860 processor with a VRAM frame buffer, and the MVX added a board with 4 more i860's (potentially up to 4 boards with 16 processors).

Both SGI and Sun were facing fierce competition in the 3-D graphics and imaging markets from Apple Computer Inc., which was introducing QuickDraw 3D, and Microsoft Corporation, which had recently acquired SoftImage and its line of simulation software. In addition Steve Jobs, founder of Apple and NeXT, had recently purchased animation producer Pixar and teamed with Walt Disney Studios on Toy Story, a full-length animation film created entirely with computers. In 2006 SGI filed for Chapter 11 bankruptcy, and although they emerged from the reorganization that same year, they filed again in 2009. The once powerful workstation company sold all of its assets to Rackable Systems for just over $40M. Also in 2009, Sun and Oracle entered into an acquisition agreement, and in 2010 it was acquired by Oracle; their sprawling Menlo Park headquarters became the new home of Facebook in 2011.

Movie 15.1 SGI Iris 2400



https://www.youtube.com/watch?v=9EEY87HAHzk

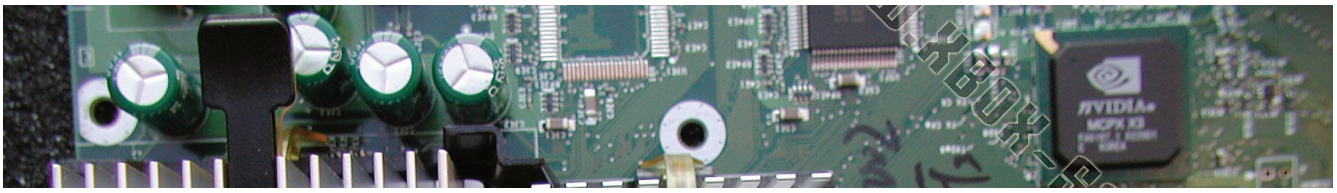
Clark, James H. *The Geometry Engine: A VLSI Geometry System for Graphics*. Computer Graphics (SIGGRAPH 82 Proceedings) 16(3) July 1982

Simons, John, "*Ghosts in the Machine: SGI Tries to Regain Its Former Luster–But Challenges Abound*," U.S. News & World Report, November 11, 1996, p. 60 (referenced at http://www.fundinguniverse.com/company-histories/sgi-history/)

For a little Sun frame buffer and graphics processor history, ?click *here*.

VizWorld.com published a blog series on the downfall of SGI titled *What Led to the Fall of SGI?*

15.3 Graphics Accelerators



Graphics accelerator boards that were developing at this time included hardware acceleration for many of the image synthesis operations, hardware pan and zoom, antialiasing, alpha channels for compositing, scan conversion, etc. The concept of adding a coprocessor to take the graphics operations away from the CPU was instrumental in bringing complex graphics images to the masses. The early frame buffers and the later accelerator boards associated with them are now embodied in the graphics cards in today's computers, such as those manufactured by NVIDIA, 3Dlabs and ATI.

HowStuffWorks.com has a reasonable explanation of the emerging role of these graphics coprocessors:

How Graphics Boards Help

> Since the early days of personal computers, most graphics boards have been translators, taking the fully developed image created by the computer's CPU and translating it into the electrical impulses required to drive the computer's monitor. This approach works, but all of the processing for the image is done by the CPU — along with all the processing for the sound, player input (for games) and the interrupts for the system. Because of everything the computer must do to make modern 3-D games and multi-media presentations happen, it's easy for even the fastest modern processors to become overworked and unable to serve the various requirements of the software in real time. It's here that the graphics co-processor helps: it splits the work with the CPU so that the total multi-media experience can move at an acceptable speed.
>
> As we've seen, the first step in building a 3-D digital image is creating a **wireframe** world of triangles and polygons. The wireframe world is then transformed from the three-dimensional mathematical world into a set of patterns that will display on a 2-D screen. The transformed image is then covered with surfaces, or rendered, lit from some number of sources, and finally translated into the patterns that display on a monitor's screen. The most common graphics co-processors in the current generation of graphics display boards, however, take the task of rendering away from the CPU after the wireframe has been created and transformed into a 2-D set of polygons. The graphics co-processor found in boards like the VooDoo3 and

TNT2 Ultra takes over from the CPU at this stage. This is an important step, but graphics processors on the cutting edge of technology are designed to relieve the CPU at even earlier points in the process.

One approach to taking more responsibility from the CPU was done by the GeForce 256 from NVIDIA (the first **graphics processing unit**, or GPU). In addition to the rendering done by earlier-generation boards, the GeForce 256 added transformation of the wireframe models from 3-D space to 2-D display space as well as the work needed to compute lighting. Since both transformations and rendering involve significant floating point mathematics (called "**floating point**" because the decimal point can move as needed to provide high precision), these tasks require a large processing burden by the CPU. Because the graphics processor doesn't have to cope with many of the tasks expected of the CPU, it can be designed to do those mathematical tasks very quickly.

3dfx introduced their GPU, the Voodoo in 1996. The Voodoo5 took over another set of tasks from the CPU. 3dfx called the technology the T-buffer. This technology focused on improving the rendering process rather than adding additional tasks to the processor. The T-buffer was designed to improve anti-aliasing by rendering up to four copies of the same image, each slightly offset from the others, then combining them to slightly blur the edges of objects to minimize the "**jaggies**" that can plague computer-generated images. The same technique was used to generate motion-blur, blurred shadows and depth-of-field focus blurring. All of these produced smoother-looking, more realistic images that animators and graphic designers wanted. The object of the Voodoo5 design was to do full-screen anti-aliasing while still maintaining fast frame rates.

The technical definition of a GPU is "a single chip processor with integrated transform, lighting, triangle setup/clipping, and rendering engines that are capable of processing a minimum of 10 million polygons per second." (NVIDIA)

The proliferation of highly complex graphics processors added a significant amount of work to the image making process. Programming to take advantage of the hardware required knowledge of the specific commands in each card. Standardization became paramount in the introduction of these technologies. One of the most important contributions in this area was the graphics API.

The Application Programming Interface (**API**) is an older computer science technology that facilitated exchanging messages or data between two or more different software applications. In other words, the API was the virtual interface between two interworking software functions, for example between a word processor and a spreadsheet. This technology was expanded from simple subroutine calls to include features that provided for interoperability and system modifiability in support of the requirement for data sharing between multiple applications.

The API is a set of rules for writing function or subroutine calls that access functions in a library. Programs that use these rules or functions in their API calls can communicate with any others that use the API, regardless of the others' specifics. In the case of graphics APIs, they essentially provided access to the rendering hardware embedded in the graphics card. Early APIs included X, Phigs, Phigs+ and GL. In 1992, SGI introduced OpenGL, which became the most widely used API in the industry. Other approaches were Direct3D and vendor specific approaches, like Quartz for the Macintosh and the Windows API.

Movie 15.2 Dawn

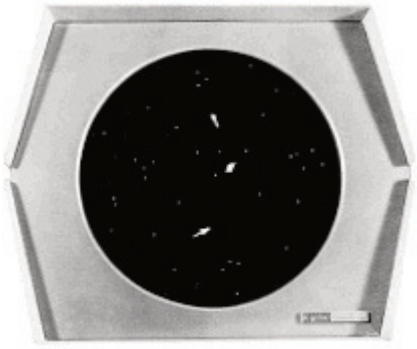


https://www.youtube.com/watch?v=4D2meIv08rQ

Demo was released in 2002 to showcase the release of the NVIDIA GeForce FX series of graphics acceleration cards.

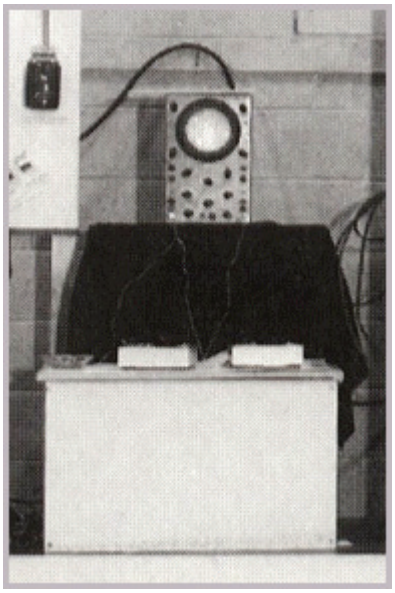
15.4 Influence of Games





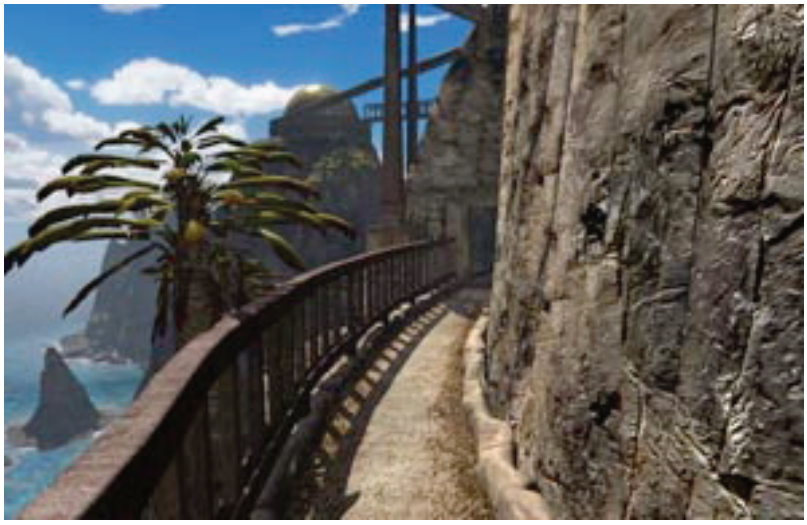
Spacewar! Display

Certainly some of the big push toward better and faster graphics image generation came from the video and arcade game industry[1] Graphics moved from the primitive images of Higenbotham's 1958 oscilloscope-based *Tennis for Two* and Steve Russell's 1961 *Spacewar* on the PDP-1, to the more realistic environments found in later popular games like *Myst* and *Riven*, EA sports games, and games for systems like the Xbox.



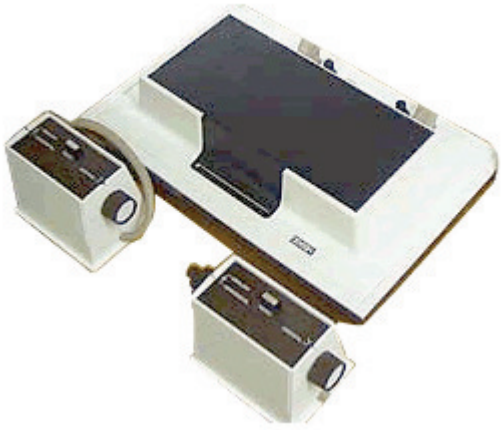
Tennis for Two

1. This section is not intended to be an in-depth treatment of the gaming history, but rather to give some flavor of innovations which influenced the evolving graphics industry. More detailed games history can be found in the link at the end of the section.



Screenshot from Cyan's Riven

The first commercial home video game was the Magnavox Odyssey, designed in 1968 and released in 1972. The game was *Table Tennis*, which was created by Ralph Baer, who worked for the defense-electronics company Sanders Associates. It was licensed to Magnavox and for a time was Sanders' most profitable line, even though many in the company looked down on game development.The Odyssey used discrete logic, a type of removable circuit card that inserted into a slot similar to a cartridge slot. The system also came with plastic overlays that gamers could put on their TV screen to simulate the playing of different "games," but only two TV sizes were supported. It also came with plastic game tokens and score sheets to help keep score, much like more traditional board games.



Odyssey Console



Nolan Bushnell

The next technology to hit the market was dedicated (nonprogrammable) video game consoles, which were often inaccurately called "analog" but actually used discrete logic. Examples of this kind of console was the Atari *Pong* game, sold by Nolan Bushnell's Atari company (Note: Bushnell was a University of Utah graduate). The Atari unit also connected to a separate television set.

Following the success of *Pong*, Atari in 1977 introduced the 2600 VCS, which is considered one of the first generation of "8-bit" programmable systems. It was the home unit modeled after the very popular arcade game *Pac Man*. Other similar systems were the Odyssey2 (1978) (known in Europe as the Philips G7000), the Channel F (1976) and the Astrocade (1977). The 2600 used the MOS Technologies 6507 CPU with 128 bytes of RAM and a TIA video processor. Memory was so expensive that there was simply no way to have a frame buffer included with sufficient resolution. Instead Atari allocated enough memory for only one line of the display at a time. When the TV completed drawing a line, the next line was transferred to the TIA (television interface adapter) while the TV was resetting for the next line. (This became known to 2600 programmers as "*racing the beam*".)

The 2600 proved to be one of the most complex machines in the world to program. Nevertheless it was that same complexity that actually made the system incredibly flexible, and when authors discovered the "tricks" the games soon started to gain in power far beyond what the original designers had ever imagined.

Work proceeded on more sophisticated systems, which can be categorized as the second "8-bit" generation. Games in this category included Intellivision (1980), Colecovision (1982), Philips G7400 (1983) (This was to be released in the USA as the Odyssey3; changing market conditions prevented its release), Arcadia 2001 (1982), Vectrex (1982) and the Atari 5200 (1982). The Intellivision used a General Instruments CP1610 16-bit CPU and 371 bytes of RAM, and 16 colors was available with 160 pixels wide by 196 pixels high (5×4 TV pixels make one Intellivision pixel). The Colecovision graphics was supplied by a Texas Instruments TMS9928A, 256×192 resolution, 32 **sprites**, and 16 colors. It used the Z80A CPU.

This generation was followed by a collapse in the video game market in North America (1984).



Famicom Console with attached disk system

The market was dismal for several years, and didn't begin returning until the introduction of the third "8-bit" generation game systems. These included the Nintendo Family System or Famicom (1985-1995), Sega Master System (1986) and the Atari 7800 (1986). At first, the Famicom console was supposed to be a 16-bit machine with a disk drive. However, the price was too high due to component prices, and so they made an 8-bit system. The Nintendo Family Computer was made intentionally to look like a toy. The Famicom design was only used in the Japanese version of this console (it was sold in the U.S. as the Nintendo Entertainment System.) It used the Nintendo 2A03 8 bit processor based on MOS Technologies 6502 core, running at 1.79MHz, with 2 KB RAM. Video memory was a PPU with 2 KB of tile and attribute RAM, 256 bytes of sprite position RAM ("OAM"), and 28 bytes of palette RAM (allowing for selection of background color), with 256×240 pixels. *Donkey Kong* was one of the first games used on this system. The Sega used an 8-bit 3.6 MHz Zilog Z80 CPU and a Texas Instruments TMS9918 derived VDP (Video Display Processor).

The fourth generation machines really started the rebirth of the industry. The most significant early entry in 1989 was the 16 bit Sega Genesis. The Genesis initially competed against the 8-bit Nintendo Entertainment System, but although it had superior graphics and sound, had a hard time overcoming Nintendo's ubiquitous presence in the consumer's home. The Genesis used the 16-Bit Motorola M68000 processor running at 7.61Mhz and a VPD (Video Display Processor) dedicated for playfield and sprite control, giving 512 colors, 80 sprites and 320 x 224 resolution. Other fourth generation machines were the Super Nintendo Entertainment System and the Philips CD-i .



Sega Genesis console and controller

Fifth generation games included the Apple Pippin (1996) (which was never marketed), Atari Jaguar (1993) (marketed as "64-bit"), Playdia (1994), 3DO (1993), the Sega Saturn (1994-1998), and the cream of the crop, the Sony PlayStation (1994) and the Nintendo 64 (1996-2002) (also marketed as "64-bit").



Nintendo 64 console and controller

The N64 specifications included a 93.75 MHz MIPS 64-bit RISC CPU (customized R4000 series) with a RCP (Reality Control Processor) which mapped hardware registers to memory addresses and an RDP (pixel drawing processor) with Z-buffer, anti-aliasing, and realistic texture mapping (tri-linear filtered MIP-map interpolation, perspective correction, and environment mapping). In comparison, the Playstation CPU was the R3000A 32bit RISC chip running at 33.8688MHz manufactured by LSI Logic Corp with technology licensed from SGI. It also contained in the same chip the Geometry Transfer Engine and the Data Decompression Engine. It could render 1.5 million flat-shaded polygons per second, 500,000 texture mapped and light-sourced polygons per second with 16.7 million colors, Gouraud shading, and texture mapping.

The Playstation console angered Nintendo who subsequently filed a lawsuit claiming breach of contract. They attempted to, in federal court, obtain an injunction against the release of the PlayStation but the federal Judge presiding over the case denied the injunction.



Nintendo Gamecube

The next models were the Sixth generation systems (starting around 1999.) They include the Sega Dreamcast, Sony PlayStation 2, Nuon, Microsoft Xbox and Nintendo GameCube. These systems had more of a PC-like architecture, as well as DVDs for game media.

The Seventh generation systems were introduced beginning in 2005. The Blu-ray Disc was used by the PlayStation 3, and HD DVD by the Xbox 360 (at least until the format went away.) The Nintendo Wii used motion as input, and IR tracking. All seventh generation consoles used wireless controllers. This generation also introduced theNintendo DS, and the Nintendo DSi, which added touch screens and cameras.

The Nintendo Wii U is considered the first of the eighth generation consoles. The portable consoles include the Nintendo 3DS, and Sony's PlayStation Vita.

For more information on these video games, with listings of the titles associated with each, go to https://en.wikipedia.org/wiki/History_of_video_games

For a detailed history of video and computer games, go to *http://www.emuunlim.com/doteaters/*

Movie 15.3 Spacewar!



Designed on a PDP-1 at MIT by Steve Russell, this is the first fully interactive video game.
https://www.youtube.com/watch?v=Rmvb4Hktv7U

Movie 15.4 Interview with Nolan Bushnell



Interview with Nolan Bushnell, founder of Atari, from the documentary Silicon Valley: A 100 Year Renaissance https://www.youtube.com/watch?v=WW_rCV254yg

Movie 15.5 Interview with Ralph Baer



Interview with the inventor of the Magnavox Odyssey, inventor Ralph Baer
https://vimeo.com/37870722

In 1975 Ralph Baer and Magnavox, creators of the first home console system – the Magnavox Odyssey – sued Atari (and many other companies, including Bally Midway, Allied Leisure and Chicago Dynamics) for their clones of the Magnavox Odyssey's 'Table Tennis' game. The Atari game in question was 'Pong.'

Due to the patents held by Baer and Magnavox parent company Sanders Associates, and coupled with the fact that there was ample evidence of Atari founder Nolan Bushnell having played 'Tennis' at a product exhibition (he actually signed a guest book indicating that he had played the game on the day in question), Atari decided to settle the case outside of the courts, for about $700,000. Other companies were also forced to pay royalties for similar 'Pong' clones.

As part of the June 1976 settlement, Magnavox would obtain rights to any Atari products released for the next year. Atari therefore decided not to release any new titles for the next year. This was the first strike from Magnavox, Sanders and Baer in what was to become a lucrative business of defending their intellectual property and receiving license fees.

In 1985 Nintendo was fast becoming a video game titan themselves, leading the invasion of the third generation of consoles, but even they could not stand up to the watertight patent laws, and after attempting to invalidate Baer's patents, they were forced to continue paying royalties to Sanders.

The following website is *The History of Video Game Lawsuits*:
http://mygaming.co.za/news/

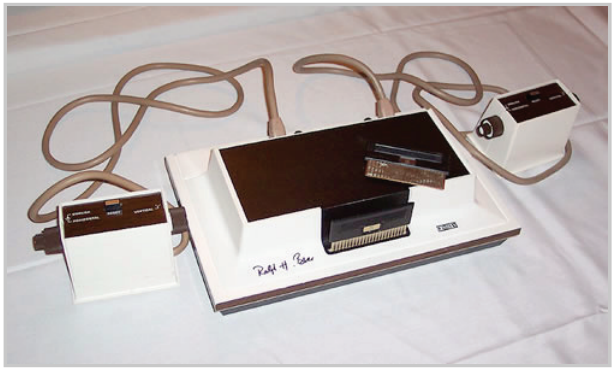
Nintendo was known in the 1980s for its draconian licensing conditions and rabid prosecution of all "unlicensed" game producers. One of the sore points among developers of the period was the fee that they had to pay to Nintendo to get their games licensed, which meant that Nintendo tested them and produced them at its own facilities (either part of the fee or for an additional cost). Another sore point was that Nintendo actually decided how many cartridges of each game it would manufacture. The company's virtual monopoly in the console market at the time allowed it to basically impose any rules that it chose, and the rules were always meant to increase profit, quality, or both. Several companies began producing games, refusing to pay the licensing fee (or being refused by Nintendo), and all were eventually forced out of business or out of production by legal fees and court costs for extended lawsuits brought by the giant

against the transgressors. The one exception was Color Dreams whose religious themed games under the subsidiary name Wisdom Tree prevented Nintendo from suing due to a fear of public backlash.

Companies that made unlicensed games include (Nintendo did not sue every one of these companies):

- Active Enterprises – only two games
- American Game Cartridges – several games
- American Video Entertainment – several small companies rolled into one
- Camerica
- Color Dreams
- S.E.I. – one game: Impossible Mission 2
- Tengen – most popular of unlicensed companies; many games
- Wisdom Tree – was not sued due to religious themes in games

Gallery 15.1 Magnavox Odyssey



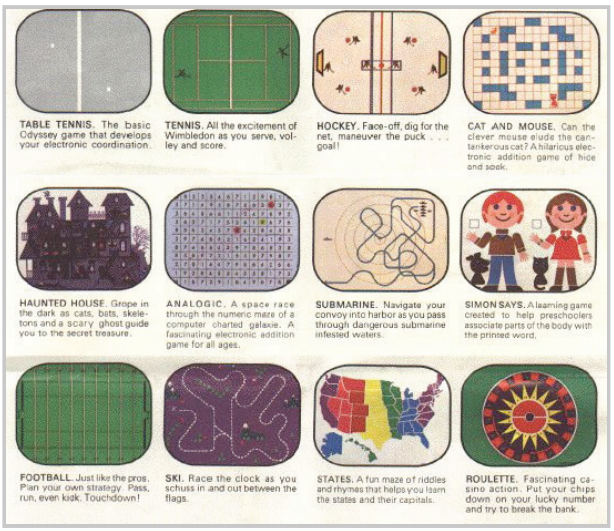
The Odyssey console and two plug-in controllers



The system had three moving components, two players and a ball, and used transparent overlays that taped to the screen for different game configurations.



Game system and packaging.



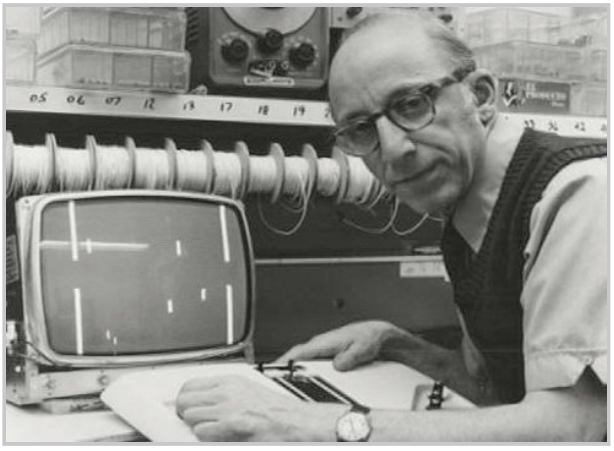
Twelve games shipped with the original Odyssey game box in 1972.



The Odyssey system shipped with plastic overlays that were attached to the TV screen to “create” different games for the user.



The Odyssey was a multi-player game.



Ralph Baer was the inventor of the Odyssey

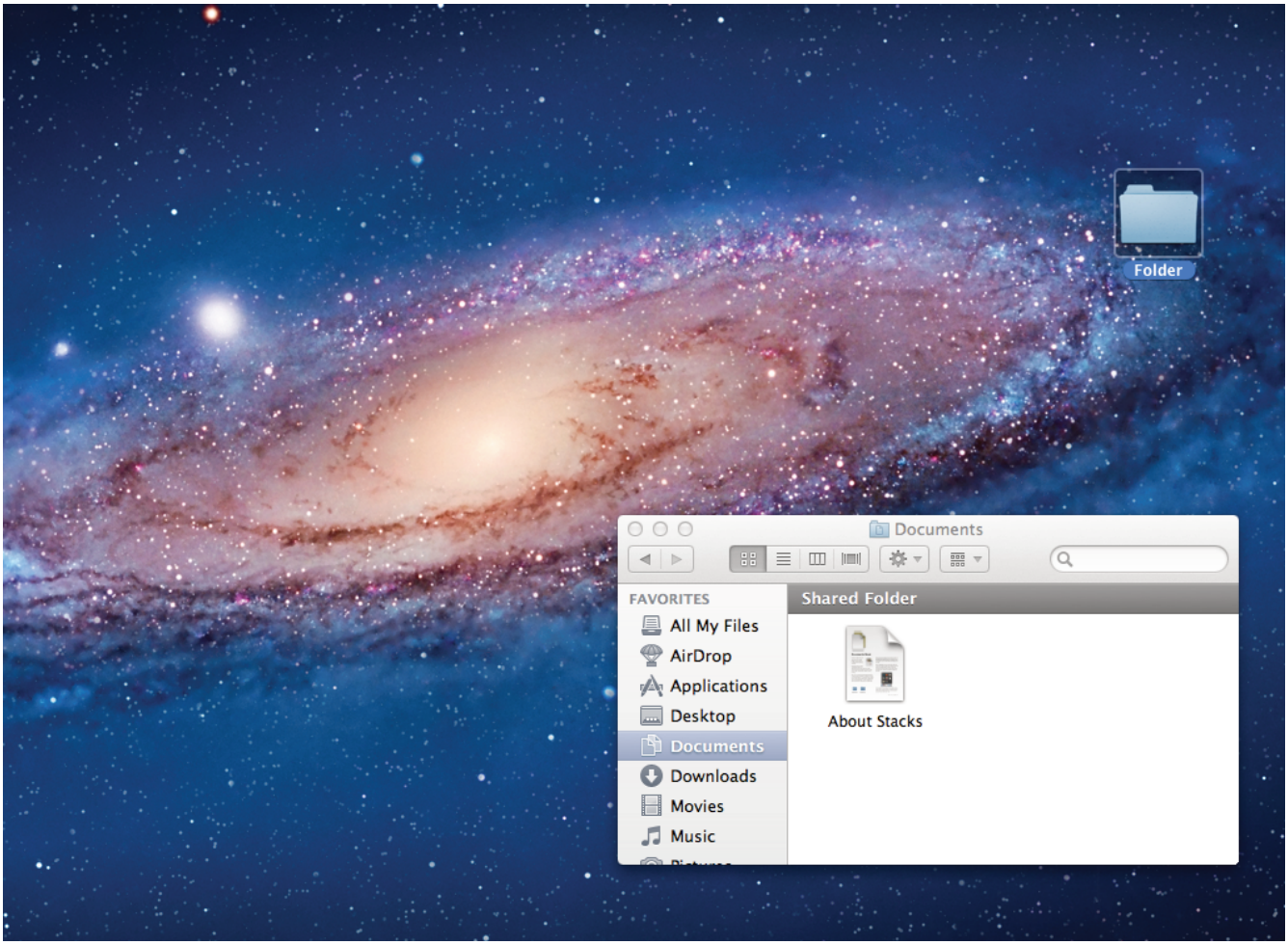


Ralph Baer, foreground, with the Table Tennis game on the screen

Chapter 16: The GUI and the personal computer

The GUI and the personal computer

> As far as the customer is concerned, the interface is the product. An interface is humane if it is responsive to human needs and considerate of human frailties.
>
> *Jef Raskin*



16.1 Xerox PARC



In 1975 the researchers at Xerox PARC (Palo Alto Research Center) moved into their permanent headquarters at 3333 Coyote Hill Road near Stanford University in Palo Alto, California. Jacob Goldman had founded PARC just five years previous, and already at this early date the research team had developed many of the ideas that shaped the future of computing.[1]

The Palo Alto Research Center's mission as directed by Xerox management was to create the office of the future. To that end they created many of the technologies we take for granted in the modern office, such as networked personal computers, with email, word processing, and laser printing, but the most significant innovation at PARC was the**graphical user interface** (GUI), the desktop metaphor that is so prevalent in modern personal computing today.

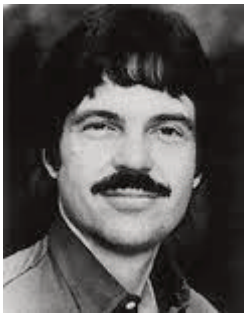
The GUI would make computer graphics an everyday part of the working environment. No longer would the display be simply lines of code and commands, it would be graphical with a true representation of typefaces and images. The bitmapped GUI display would help promote the concept of WYSIWYG (what you see is what you get) allowing people to laser print exactly what they saw on the screen.

1. Thanks to graduate students John Buck and Jon Gladden for their contributions to this chapter.

In workstations of the past, graphics and commands where split between three different screens, a vector device for line graphics, a text display for entering commands, and a video / raster graphics screen coupled with a frame buffer to display the final rendered result. Xerox PARC combined these separate technologies into one raster graphics screen along with an easier way of issuing commands: the pop up menus, icons, and desktop metaphor of the graphical user interface. While mainline computer engineers scoffed at the idea of one computer for each person, the Xerox team built the Alto personal computer. Traditional computer applications centered on number and data manipulation; the Xerox team focused on words, design and communications.



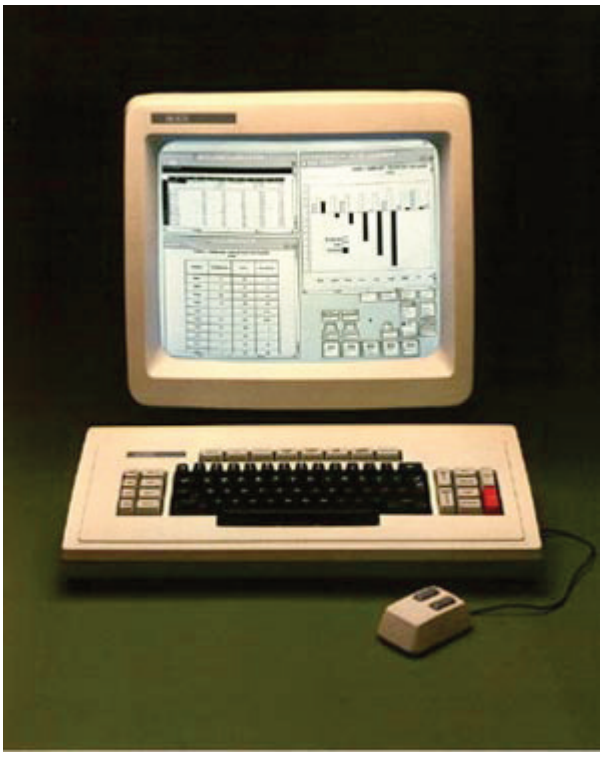
Alto computer



Alan Kay

The researcher roster at PARC reads like a who's who of the CGI world. As with many other areas of computer graphics, researchers from the University of Utah would play a key role in the development of the GUI and other products developed at PARC. The idea for GUI was actually first developed by *Alan Kay* from the University of Utah who went to work at PARC on the Alto project in 1970. Kay and Ed Cheadle built a computer called FLEX at the University of Utah between 1967 and 1969 that included the rudimentary elements of a GUI, including multiple tiled windows and square icons representing data and programs.

The first GUIs tried at Xerox PARC were very difficult to work with and depended too much on the processor to re-draw each bit when moving overlapping windows around. In 1974 a PARC researcher named *Dan Ingalls* , who was one of the principle architects of the *Smalltalk* object oriented language, invented a procedure for the movement of whole blocks of bits on the screen called "Bit Blit", or *BitBLT*. This display algorithm allowed overlapping windows to be quickly shuffled around the screen without overtaxing the processor.



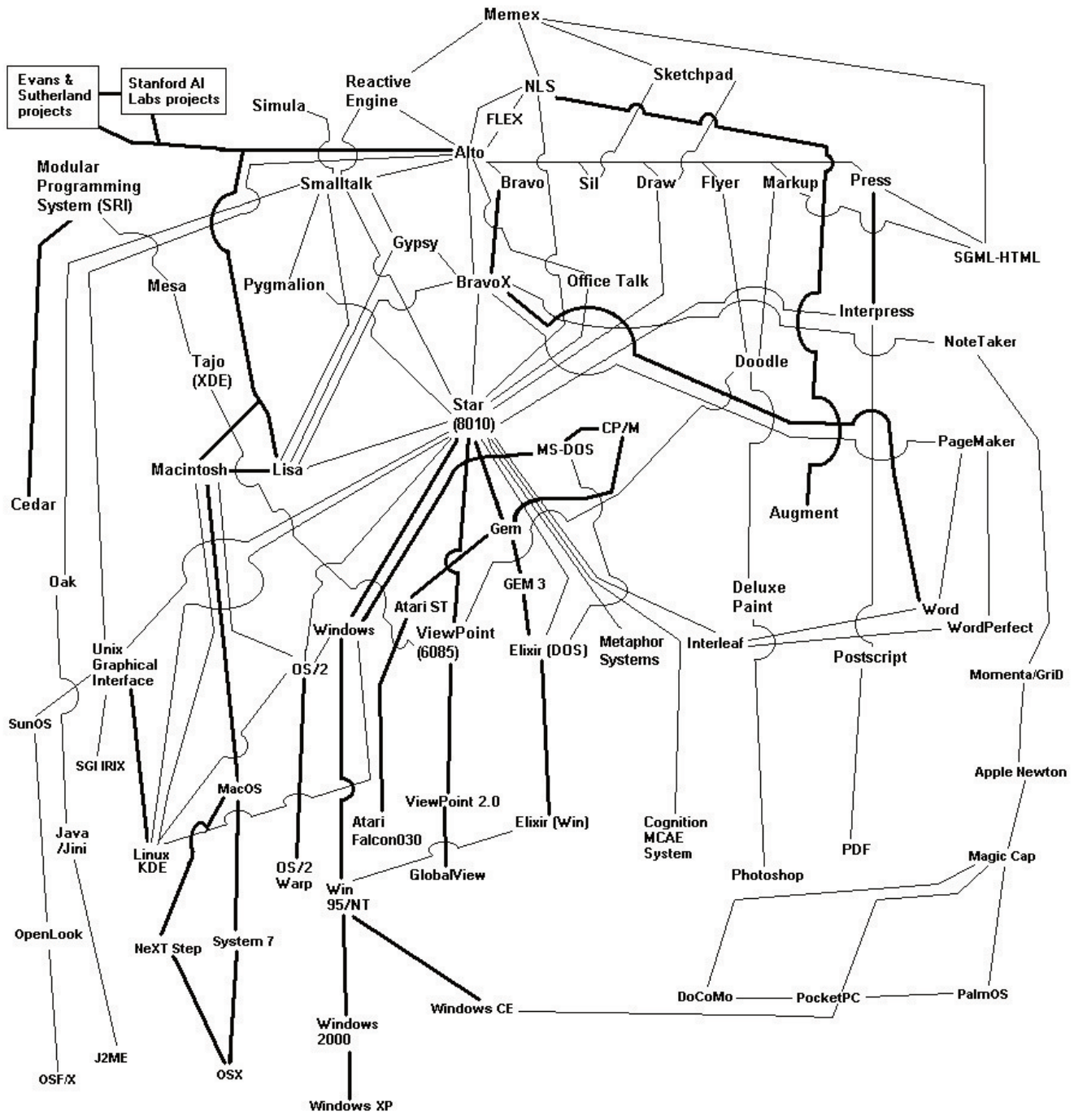
Xerox Star Computer

The Xerox Star was the first commercial personal computer to use the now common desktop metaphor. David Smith, developer of the Star interface, said in a 1982 article:

"Every user's initial view of the Star is the Desktop, which resembles the top of an office desk, together with surrounding furniture and equipment. It represents a working environment, where projects and accessible resources reside. On the screen are displayed pictures of familiar office objects, such as documents, folders, file drawers, in-baskets, and out-baskets. These objects are displayed as small pictures, or icons."

PARC was initially divided into three units: the Computer Science Lab (CSL), the Systems Science Lab (SSL), and the General Science Lab (GSL). The CSL, run by Bob Taylor, was most responsible for the development of the graphical user interface. Taylor had worked on the ARPAnet, (a distributed network of computers, the predecessor to the Internet) and brought the idea of networked computers to PARC.

By 1979 there were hundreds of Altos networked together with more traffic and 'nodes' than the entire ARPAnet. Xerox PARC even had the world's first computer virus called a 'tapeworm' because it would eat it's way through the Ethernet and consume all available resources. Like many of PARC's innovations networking was ahead of it's time, and would not be widely available in personal computers for another decade.



PARC contributions have resulted in a plethora of products and other research results

In 1979, Xerox decided against marketing the Alto system. By then the organization barely resembled the buoyant company that a decade earlier had challenged both IBM and the office of the future. External factors including fierce competition, government antagonism, and economic recession all marked Xerox's slide from overconfidence to loss of confidence. Internal forces were even more combustible, as the company's research, finance, and marketing groups each pursued a separate vision of the "right" Xerox future. In the end, the company

that invented the first version of the personal computing future found itself struggling to recapture the advantages of its copier past.



Computer Magazine Cover (Sept. 1989)

Alto had the ability to show other computers on the network as icons on it's graphical desktop. Much later Macintosh acquired this ability. With the birth of the Internet and the World Wide Web, computers could network to others across the world, but this was done with a separate application that was at first nongraphical (telnet, text-based FTP software). Later applications for accessing the internet became more GUI-like but were not part of the operating system (TurboGopher, Fetch, Anarchie). With the introduction of the first graphical web browser, Mosaic, in 1993 accessing the internet began to look more like an environment one would see with a GUI.

With the release of Windows 95 and NT, Microsoft attempted to blur the distinction of the web browser application and operating system by bundling Windows 95 with Internet Explorer. The windows and interface of Windows 95 could be set so that browsing the local computer looked almost the same as browsing the Internet. Microsoft got into legal trouble because the bundling strategy was seen as an attempt to block competition from Netscape and other browsers. (See Landgrave article listed in bibliography box below)

John Warnock (University of Utah) helped develop Interpress and other printing and page description systems at PARC which allowed the Alto to become the first WYSIWYG computer when coupled with Xerox's laser printer. Later Warnock founded Adobe Systems which along with Apple computer helped bring about the desktop publishing revolution of the late 1980s . The combination of the Macintosh, the LaserWriter, and Adobe's page description software would forever change the world of publishing, typesetting, and graphic design.

Larry Tesler at PARC, who would later be part of the Apple LISA development team, began work on Gypsy, the world's first user friendly word processing application using pop-up menus and icons in 1974. Gypsy was later to become the basis for Microsoft Word when it's co-creator Tim Mott and others at PARC went to work at Microsoft. Gypsy was essentially the world's first desktop publishing software with advanced features such as drawing and editing graphics within the same application as the word processor. These features began to emerge in software packages such as Adobe InDesign and QuarkXpress.

It is widely believed that the Xerox corporate management never realized what they had at PARC — it seems that they never shared the same vision as the researchers. The innovations developed there were never marketed successfully under the Xerox name. It took outside companies to market PARC innovations in GUI and **WYSIWYG** to make them the standards they are today.

"Office automation has emerged as a full-blown systems approach that will revolutionize how offices work."? (Business Week, June 1975)

"The basic purpose of Xerox Corporation is to find the best means to bring greater order and discipline to information. Thus, our fundamental thrust, our common denominator, has evolved towards establishing leadership in what we call 'the architecture of information'. What we seek is to think of information itself as a natural and undeveloped environment which can be enclosed and made more habitable for the people who live and work within it. "? (C. Peter McCulough, CEO Xerox Corporation)

"None of the main body of the company was prepared to accept the answers. So there was a tremendous mismatch between the management and what the researchers were doing and these guys had never fantasized about what the future of the office was going to be. When it was presented to them they had no mechanisms for turning those ideas into real live products and that was really the frustrating part of it. You were talking to people who didn't understand the vision and yet the vision was getting created everyday within the Palo Alto Research Centre and there was no one to receive that vision."? (John Wamock)

"People came there specifically to work on five year programs that were their dreams." ?(Adele Goldberg, Former Xerox PARC Researcher??)

"Everybody wanted to make a real difference, we really thought that we were changing the world and that at the end of this project or this set of projects personal computing would burst on the scene exactly the way we had envisioned it and take everybody by total surprise." (?Larry Tesler)

Here is a sampling of PARC contributions. To view a timeline of GUI contributions, see Section 5 in this chapter.

- The Alto – The first personal computer, the Alto embodied such innovations as the world's first WYSIWYG editor, commercial mouse, graphical user interface (GUI) and bit-mapped display.
- Client/Server Architecture – This approach was a paradigm shift that moved the computer industry away from the hierarchical world of centralized mainframes downloading to dumb terminals and toward more distributed access to information resources.
- Ethernet – Ethernet became the global standard for interconnecting computers on local area networks. The Ethernet standard spawned a series of increasingly sophisticated networking protocols that not only enabled distributed computing, but led to a re-architecting of the internal computer-to-computer communication within Xerox copiers and duplicators. The 10 Series copiers were the first to use numerous built-in microcomputers with a low-bandwidth Ethernet as the communications interface.
- Network Architecture – The development of Ethernet, Alto and research prototypes of networking protocols for distributed computing led to the development of XNS, Xerox' robust, leading-edge networking protocol. This led to the Corporate Internet, an internal wide area enterprise network that was well ahead of its time in enabling employees to exchange formatted documents worldwide with speed and ease. In fact, with Xerox' STAR system, 1981, users were able to access file servers and printers around the world through simple point-and-click actions, a functionality that has yet to be matched by today's computing systems.
- Internet Standards – PARC scientists are playing a leading role in designing the protocols that will

govern and define how the Internet will work in the future. The "M-Bone" multicast backbone, a collaboration between PARC and several universities from around the world, was first implemented at PARC and has been delivering realtime video over the Internet since 1992. Currently, a PARC research team has been chosen by the World Wide Web Consortium to lead the design for the next generation of HTTP.

- **Glyphs** – PARC is a world leader developing embedded data schemes that transform paper into a user interface. Glyphs are used in many applications, including data verification and finishing applications.
- Information Visualization – PARC's unique approach to the visualization of information uses people's perceptual and cognitive capacities to help them deal with large amounts of information. The approach was originally used in 3-D Rooms and was an integral technique used in the Xerox product Visual Recall. The hyperbolic browser, which could revolutionize the way people access information on the Internet, and other focus-plus-context visualization techniques are part of the foundation for Inxight, a Xerox New Enterprise Company.
- Collaborative Tools – Work on collaborative tools, beginning with Colab, resulted in the development of a product for document-based group collaboration called LiveBoard. This technology, which spawned a business unit called LiveWorks, enabled colleagues – both locally and in remote sites – to work together using real-time, multi-media documents. More recently, research on how a sense of place can create more meaningful interaction on the Internet has turned into a spin-out company called Placeware, in which Xerox holds a partial interest
- Flat Panel Display – Work in amorphous silicon led to the development of thin film transistors. Arrays of these devices now provide for a new generation of flat, print-quality displays. This technology, resulted in the formation of dpiX, a Xerox New Enterprise Company. The panels that are used to make electronic documents as easy to read as paper documents have also found application in document scanning and digital X-ray imaging.
- Laser Printing – Electronic printing provided a means of seamlessly transferring digital documents into the paper domain. The original idea of modulating a laser to create an electronic image on a copier's drum migrated from Rochester to the newly-formed PARC where it became the basis for Xerox' multi-billion dollar printing business. The early Raster Output Scanner optical designs for Xerox laser printers were also developed at PARC. This invention changed the entire notion of documents and document processing.
- Page Description Languages – Page Description Languages enable the construction of documents from higher-level sources. They are the intermediaries between tools for creating documents and devices for displaying them. Press, the first PDL, was developed by PARC scientists and greatly influenced the design of Interpress and PostScript.
- Device Independent Imaging – A software document architecture that enables device dependent aspects of imaging to be cleanly separated from generic imaging operations, Device Independent Imaging has been a research thrust at PARC for a number of years. This work is enabling Xerox printing products such as DocuPrint to drive different Xerox printers from a common software base.
- Laser Diodes – PARC's laser research has made Xerox a world leader in semiconductor laser diodes, resulted in hundreds of patents and spawned Spectra Diode Laboratories. Laser diodes are used in all new Xerox printing products.?Multi-beam Lasers – PARC was the first organization in the world to create a multi-beam laser diode and Xerox is, to date, the only printing company to have this capability. The dual-beam laser emits two beams rather than the a standard single beam, making it

possible to print twice as fast. The dual-beam laser is in use in Xerox' flagship product, the DocuTech 180, and is being incorporated in Xerox' new DocuCenter color products.

- Blue Lasers – In October of 1997, Xerox PARC was the first printing company to create a blue laser. The reduced wavelength of a blue laser allowed much higher resolution printing than was possible with standard red and infrared lasers.
- DocuPrint – The system that drives Xerox high-end, network based printers brought together two decades of knowledge and a number of technologies including higher level languages, integrated software for page description and device independent imaging.
- Integrated AI Environments – Interlisp is an ACM award-winning integrated environment that supports artificial intelligence applications. It combines ideas for rapid prototyping with explicit knowledge representation. With the Loops object-oriented extensions, it was used to develop a number of valuable knowledge-based systems for Xerox.
- BITbIt – This small but important invention enables programmers, without special hardware, to manipulate images very rapidly. The "bit blasting" computer command enables the quick manipulation of the pixels of an image and was built into the instruction code of the Alto.
- Mesa/Cedar – Mesa is a system programming language developed at PARC that incorporated mechanisms for making software more reliable, while supporting rapid development. Many of the ideas from this language were used in the development of ADA, the standard DOD language. Mesa was used to implement much of DocuTech software. Cedar, a successor to Mesa also developed at PARC, enabled the rapid development of the DocuPrint system.
- Object-Oriented Programming – The notion of objects that are described and addressed individually and that can be linked together with other objects without having to rewrite a entire program has revolutionized the software industry. PARC's early and continuing work in this area makes it a world leader. SmallTalk, developed at PARC, was one of the first successful object-oriented languages and led to the spinoff of PARCPIace Systems. All current software development at Xerox uses an object-oriented methodology.
- Expert Systems – PARC researchers developed the Interlisp-D environment for Al programming as well as a variety of applications utilized within Xerox. For example, Trillium enables the quick simulation of new user interface designs and Pride captures engineers' experience and rules of thumb for designing paper paths using pinch rollers.
- VLSI Design Methodology – A new representation of VLSI (very large scale integration) integrated circuit designs led to a new generation of computer-aided design (CAD) tools, reduced design time and spawned the silicon foundry industry.?Linguistic Compression Technology – Based on an understanding of the deep structure and mathematical properties of language, this technology is used for visual recall, intelligent retrieval and linguistic compression. This work has had a major impact on the automatic processing of language structures and is one of the key research areas underpinning Xerox' Multilingual Suite of products.
- Constraint-Based Scheduling – This technology uses intelligent modeling to create real time machine control, providing the planning software that enables the DocuCenter "plug and play" family of copiers. It gives Xerox a competitive hardware advantage by enabling very effective and efficient machine control at the customer site. Reusable models also improve time to market and performance quality.
- Smart Service – Smart Service provides workers with the tools for generating information systems

that enable productivity and learning through lateral communication. One implementation is the Eureka knowledge-sharing system which has helped field service technicians in France, Canada and the U.S. dramatically improve their productivity and the quality of service delivered to Xerox customers.

- Work Practice Studies – Ethnographic studies conducted by PARC social scientists have revealed how people really work and what they need from technology. By observing the practices of customers using copiers, field service technicians doing repairs and people doing office work, PARC researchers have evolved a community based approach to the design and use of technology.

Movie 16.1 XEROX STAR demo (1982)



http://www.youtube.com/watch?v=Cn4vC80Pv6Q

Marcin Wichary's excellent collection of GUI material – *GUIdebook: Graphical User Interface Gallery*
http://www.guidebookgallery.org/

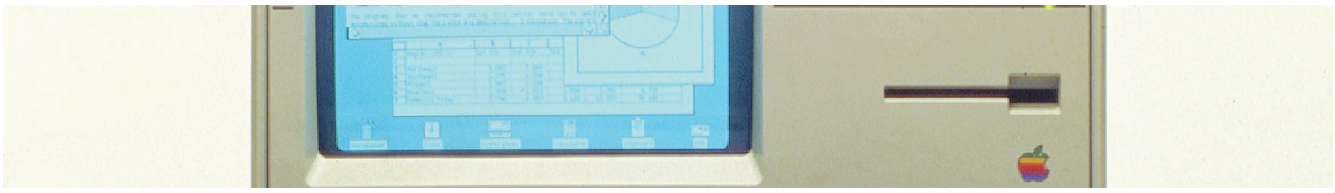
The Graphical User Interface
http://www.sitepoint.com/article/real-history-gui

Xerox PARC history
?*http://www.parc.com/about/*

1972: Xerox PARC and the Alto
http://www.cnn.com/TECH/computing/9907/08/1972.idg/

Microsoft's Settlement: the End of an Era, Tim Landgrave
http://www.techrepublic.com/article/microsofts-settlement-the-end-of-an-era/5035167

16.2 Apple Computer



A few miles down the road from Palo Alto was a man ready to share the vision of the PARC researchers.[1] At the height of Apple Computer's early success in December 1979, Steve Jobs, then 24, had a privileged invitation to visit Xerox PARC. Jobs and engineers from Apple visited Xerox PARC and were given demonstrations of the Alto and it's graphical user interface. They would later incorporate much of what they saw into the design of the Lisa and Macintosh. **Bill Atkinson** and the architects of Lisa had begun working on a GUI before the demonstration at PARC, but it was far more static than what showed on the Alto.

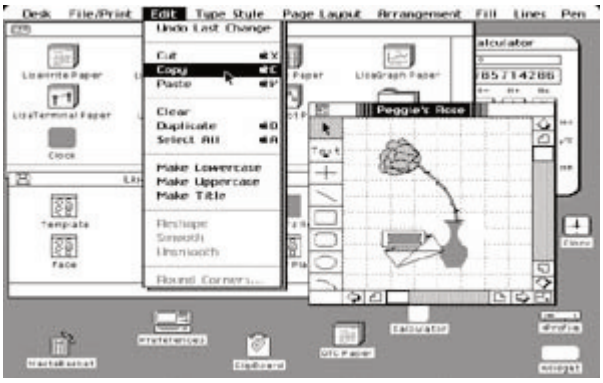


Apple Lisa

In January 1983, Apple Computer officially unveiled the Lisa. It featured a 5-MHz 68000 microprocessor, 1MB RAM, 2MB ROM, a 12-inch B/W monitor, 720×364 graphics, dual 5.25-inch 860KB floppy drives, and a 5MB Profile hard drive. It was slow, but innovative. Its initial price was $10,000. ("Lisa" stands for Local Integrated Software Architecture.)

1. *Triumph of the Nerds* (PBS Transcripts, Part III - http://www.pbs.org/nerds/part3.html

The original Lisa interface was less reliant on the mouse; it used a "softkey" as it's primary pointing device, which was essentially arrow keys on the keyboard. The demo gave those at Apple that were devoted to a more dynamic GUI for the Lisa the proof they needed that the graphical desktop was the direction to head. Atkinson recalls that "mostly what we got was inspiration from the demo, and a bolstering of our convictions that a more graphical way to do things would make a business computer more accessible." Jobs liked what PARC had done with the GUI so much that he convinced Larry Tesler to switch from PARC to Apple and help him develop the interface for the Lisa.



Lisa Desktop image

> "They showed me three things. One of the things they showed me was **object-oriented programming**. Another one they showed me was a networked computer system … they had over a hundred Alto computers all networked using email etc. I didn't even see that. I was so blinded by the first thing they showed me which was the graphical user interface. I thought it was the best thing I'd ever seen in my life. Now remember it was very flawed, what we saw was incomplete, they'd done a bunch of things wrong. But we didn't know that at the time, but still though, the germ of the idea was there and they'd done it very well, Within you know, ten minutes, it was obvious to me that all computers would work like this some day."? *Steve Jobs, Apple Computer?, commenting on his visit to Xerox PARC.*

The Apple Lisa did not sell well because, like the Xerox STAR, it was too expensive ($10,000) as compared to IBM PCs of the day. 1984's Macintosh was the first personal computer with a GUI to be marketed successfully because of it's more reasonable price and well planned advertising strategy. At first the Mac did not sell as well as expected, because of it's lack of software; MacPaint and MacWrite were not enough for businesses who needed spread sheets and accounting software.

The following segment is from an *article* in PCworld online in honor of the 20th anniversary of the Mac.

Remembering 1984

But the Macintosh marketing memories[2]

"It was the autumn of 1983. Business Week magazine had an IBM personal computer on its cover, with the ominous words, And the winner is...IBM. Apple Computer was in a world of hurt. The Apple II had lost its competitive edge. The Apple III was a sales disappointment and the Lisa, introduced in January 1983, was a financial failure. Great expectations were being placed on the Macintosh, scheduled to launch on January 24, 1984. Yet there was skepticism both in and outside the company. There was no hard disk support. The screen was too small and it wasn't in color. There was limited software. Yet many believed that the Macintosh was indeed The computer for the rest of us. The engineers knew it. The software guys knew it. And most of all Steve Jobs knew it. The challenge for the Mac Marketing Team was simple: They had to establish and hold a beachhead. Or else they and the product would die. The introduction of the Macintosh computer launched a comprehensive and integrated approach to high-tech marketing. Much of what was highly innovative in 1984

2. The Computer History Museum hosted a panel session in 2004, telling the true story of the early Macintosh marketing. The following text describes the panel session introduction. The entire 2 hour session can be viewed at https://www.youtube.com/watch?v=JTVDWGtf9m4

is now standard fare for all product introductions." begin for most of the pioneers with the “1984” ad that played during the Super Bowl the week of the Macintosh’s launch. Crafted by Hollywood director Ridley Scott, it was dramatic and artsy — and, as several of the principals recall, it almost didn’t run.

A preview of the ad was greeted with foot-stomping, whistling applause from the sales force at a fall meeting, several members of the original Macintosh marketing team say. But the Apple board of directors was much less impressed, and in fact ordered ad agency Chiat/Day to try to sell the Super Bowl advertising time spots. When the agency reported it couldn’t unload the 60-second spot by the deadline, Apple’s board suggested swapping in an Apple II advertisement–but none was suitable. So the board acquiesced, the spot ran–and the Mac made its mark on the advertising field as well as on the technology world. Today, the Super Bowl is often the showcase for innovative advertisements.

“At the next board meeting two weeks later, they summoned the senior members of the Macintosh team,” [Mike] Murray says. “We went into the board room, and they all stood up and applauded.”? Although broadcast just once, the ad is still a marketing message for Apple. It was eventually preloaded on some Apple systems and is available for download.

Movie 16.2 Apple’s famous “1984” Macintosh ad



The “1984” commercial introduced the Apple Macintosh. It was conceived by Chiat/Day, and directed by Ridley Scott.
https://www.youtube.com/watch?v=2zfqw8nhUwA



From '1984' Ad, with iPod added.

At the 2004 MacWorld, ***Steve Jobs*** *presented the 1984 ad again as part of his keynote speech. In this version, the hammer-wielding female was outfitted with an Apple ?t-shirt and an iPod. The remade ad can be seen by clicking here.*



The hammer throwing athlete/actress is Anya Major, who also appeared as the Russian border guard in Elton John's music video Nikita.

Movie 16.3 *Nikita – excerpt*

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/nikita-excerpt.m4v

The following description of the Apple/PC developments is from the introductory chapter of a 1994 Masters thesis written by Lionel A. Smith (http://lionels.orpheusweb.co.uk):

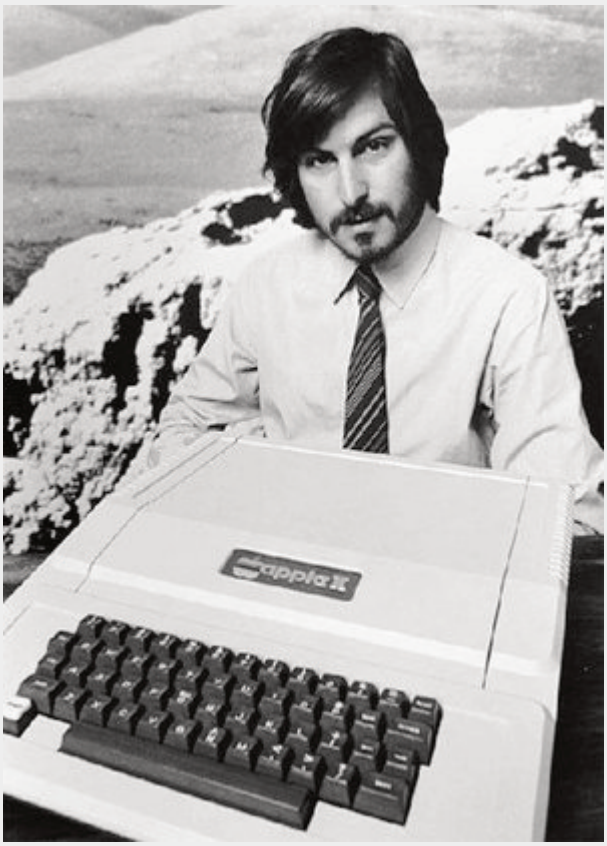
Hewlett-Packard minicomputer electronics engineer and programmer, **Steve Wozniak**, had developed an interest in microcomputers through the Homebrew Computer Club. Wozniak, whose real forte was simplifying circuits by making components fulfill more than one function, proceeded to design a small computer with video-terminal capability around the Mostek 6502 microprocessor (because at $25 it was the only one he could afford).

Electronics engineer, and entrepreneur Steve Jobs, the son of a salesman, had, while working for Atari, engaged the talents of Wozniak in hardwiring the video game Breakout. Wozniak reduced the chip count to 44 (when normal chip counts for this type of game were 150-170).The design was too complex for Atari engineers to understand and a pre-production redesign was required. Wozniak's talent for minimalist design was a vital factor in product commercial viability by keeping construction costs down.

Demonstrations of Wozniak's microcomputer at the Homebrew Club quickly led to firm orders for production machines. Hewlett-Packard, having declined an interest in the microcomputer designed by their employee, gave Wozniak a legal release, opening the way for the formation of Apple Computer and sales of the Apple I.

Soon Jobs and Wozniak realized that what the world wanted was a personal computer that only required connecting to a domestic TV to be made ready for use, so Wozniak designed a successor.

The Apple II, also based on the Mostek 6502 microprocessor, scored immediate success with its color graphics and use of discs for data and program storage. The operating system, also supplied on disc, required loading into RAM during startup. Sales of this machine accelerated fast enough for third parties to become interested in developing hardware expansions and software.



Jobs holding Apple II

The spreadsheet, as an aid to financial planning and what-if analysis was the concept of Dan Bricklin who first produced a demonstration version written in BASIC on an Apple II. It was with this demonstration that the use of the slash character to initiate a command first appeared, which became such a familiar feature of spreadsheet software including Lotus 1.2.3. Bricklin teamed up with Bob Frankston and created the Software Arts company to produce the full assembly language version, VisiCalc. The combination of VisiCalc and a disc system was so successful that many Apple IIs were sold into the business community, enhancing Apple's credibility. Indeed, IBM held up the announcement of the IBM PC until a VisiCalc conversion was ready.

Thus, in the early nineteen-eighties, there were two de-facto standards for personal computers; the S-100 bus–CP/M camp and the Apple following. There were many other proprietary machine architectures, each with a unique combination of microprocessor, bus, memory architecture and file system formats, and transfer of data between formats was all but impossible.

When the IBM Personal Computer (PC) was introduced in August 1981, little did the world suspect that a standard was being set, a standard which would continue to make its existence strongly felt as far into the future as 1994, and possibly beyond.

IBM brought their first PC to market in a little over thirteen months from inception. This was remarkable for a company whose project gestation period was usually measured in years. A major factor in the short development time was that IBM had taken the unprecedented step, for an industry giant noted for developing products which were proprietary through and through, of using existing hardware components from external vendors. The use of many design elements of IBM's earlier System/23 DataMaster was also a major factor in the speed of development and expansion cards for this system could be used in the new machine.

More remarkable was the adoption of an operating system from the relatively small Microsoft company, who also supplied a BASIC language interpreter. IBM also offered CP/M-86, a 16-bit version of the 8-bit CP/M from Gary Kildall's Digital Research. The first DOS was 86-DOS for S-100 computers upgraded with the Intel 8086 CPU. DOS-86 was produced by Seattle Computer Products, the rights of which were bought by Microsoft.

The well thought out synthesis of the best features from existing microcomputers and the close compatibility with CP/M systems ensured marketing success beyond even IBM's expectation. The non-proprietary nature of the PC system architecture encouraged many other manufactures to begin building compatibles. This development had far-reaching consequences for the way in which the personal computer industry developed.

Although the 8088 microprocessor operates at 16-bits internally, it communicates with other components of the PC over an 8-bit bus. The advantage of this design strategy was that DataMaster features and 8-bit logic chips, which were plentiful and cheap, could be used.

Accessing memory over an 8-bit bus caused a bottleneck. In 1983 IBM introduce the PC/XT which was also built around the 8-bit Intel 8088 microprocessor. The PC/XT used version 2.0 of PCDOS, which for the first time used a hierarchical filing system capable of dealing with the much larger capacity hard discs with which the XT could be equipped.

Meanwhile Apple had embarked on a new project, code named Lisa, to develop a new office computer. In search of funds, Apple's Steve Jobs approached Xerox, whereupon he and other members of the Lisa team visited Xerox's Palo Alto Research Center (PARC), where they were shown the Alto. The Apple team was so impressed with the Alto's sharp graphics, displaying a virtual desktop complete with usable documents and small on screen pictures called icons, they decided that the Lisa would be the Alto for the masses.The Apple team's enthusiasm and ideas so impressed Larry Tesler, a member of the Alto's design team that he joined Apple.

High resolution graphics demand fast microprocessors and ample RAM, both very expensive commodities in 1983, the resultant high unit price was the major factor in the Lisa's commercial failure. Undeterred, the Apple team carried on with development and launched a scaled down version in 1984 under the name Macintosh, based on the Motorola 68000 microprocessor.

The Macintosh with its **WIMP** based GUI and its lack of program modality was a revelation to a world used to a command line, or at best menu driven interface. The Macintosh was to have a profound effect on the future development of personal computers. The Mac, as it became known, with

its GUI-fronted operating system was presumably what Byte's Editor in Chief had in mind when he wrote:

> *"I'd buy an operating system any day that takes a long time to run a given program but which makes me more productive by communicating with me in useful ways." ?(Morgan, 1981).*

In 1984 IBM introduced the IBM PC/AT built around the new Intel 80286 16-bit microprocessor. The 80286 apart from being capable of faster throughput than previous models offered some advanced features. Amongst these were processing parallelism and hardware implemented task switching with program protection.

Unfortunately in maintaining backward compatibility with version 2, the new 3.0 version of PCDOS did not support either **multitasking** or multiuser environments. Thus, the AT was primarily used as a more efficient PC/XT and could still only make use of a maximum of 640k of user memory in 'real address mode'. Users wishing to take advantage of the possible 16 megabytes of memory, as well as the multitasking and multiuser capability were expected to wait for the forthcoming XENIX operating system.

A major architectural feature of the original PC was the use of an expansion bus equipped with connectors, or slots, to take adaptor cards for interfacing with peripherals in particular visual display units (VDUs) and hard drives. The expansion slot data width is one factor which determines how quickly data flows between the microprocessor and the peripheral. The original PC slots had an 8-bits wide data path increased to 16-bits on the AT to match the data width of the 80286. Both the 8-bit and the 16-bit bus specifications are known as the ISA.

Compatible makers continued to build enhanced versions of the PC for sale at competitive prices, introducing all manner of compatibility issues as a result. IBM when developing a 32-bit bus to suite the new 32-bit Intel 80386, and realizing that they had lost control of their architecture, produced MCA. MCA used many proprietary methods and components with which IBM hoped to defeat the compatible makers. The first systems with MCA were the PS/2 range, launched in 1987, this included models built around the 80386, 80286 and 8086. PC compatible manufacturers were allowed to use MCA architecture providing they paid IBM substantial royalties.

To avoid paying such royalties, a consortium of compatible makers, led by Compaq, responded by developing the 32-bit EISA bus which, apart from being faster and cheaper to implement, had the added advantage of maintaining compatibility with existing 8MHz ISA bus adaptors.

The launch of the Macintosh had focused the computer world's attention on the user interface and where Apple led many were soon to follow. Digital Research produced GEM which could run under CP/M-86 or TOS on the Atari ST, and Microsoft produced Windows for the PC, both of which incurred Apple's wrath for being to close to the look and feel of the Mac interface, Commodore having bought out a small company Amiga, launched a computer of that name using Intuition, as a GUI.

IBM with Microsoft produced a new 16-bit operating system OS/2 for the PS/2 range. OS/2 was designed to give a GUI, Presentation Manager, a head start by clearing away the 640k memory limitations of MS-Dos. Meanwhile the Unix camp were evolving their own many flavors of GUI such as Motif, DEC-windows, Open Look, Open Desktop and NextStep. Nextstep is the user interface developed to run under Unix on the Next Computer, the product Steve Jobs nurtured sometime after leaving Apple.

The move towards GUIs was generally welcomed by the computing fraternity, but there was one big drawback, especially for users of PC systems running MS-Dos. GUIs such as Windows, with their

resolutions of 640 x 480 pixels or larger as opposed to the typical 24 lines of 80 characters, increased dramatically the amount of video traffic.

Furthermore, if ram is limited, large volumes of data need to be swapped out to disc frequently. When this is achieved over the 8Mhz ISA bus then systems can become sluggish and unresponsive, no matter how fast and capable the microprocessor.

With the introduction of the fast 80486 CPU, overcoming the ISA bus bottleneck became a high priority, especially where graphics adaptors and Windows, SCSI interfaces often used by CD-ROMS and scanners and hard drives were concerned. One answer appeared in the concept of the local bus, with which peripherals are connected directly to the CPU and/or ram. A number of manufacturers, including Compaq, Dell and Hewlett-Packard developed their own proprietary local bus systems which, although technically adequate, restricted adaptor choice to specifically designed cards.

The first widely adopted local bus standard was the 32-bit VESA local bus, (VLB or VL bus). This bus could be driven as fast as the clock of a 33Mhz processor, higher speeds requiring the implementation of wait states. The VLB has a maximum rated throughput of 128-132 Mbs compared to the ISA bus maximum of 8Mbs. VESA is a voluntary standard which some manufacturers have only partially implemented and it is in the process of being updated to cope with the 64-bit wide data path of the Pentium CPU.

PCI is an Intel initiated local bus standard which has been slow to gain wide acceptance because of its late introduction. With the increasing numbers of Pentium based systems PCI is becoming more widely accepted.

Many of these more recent bus technologies overcome the DMA and IRQ configuration troubles which continue to dog the majority of systems which still use the ISA bus. Many of these problems will not disappear until Windows dispenses with the services of the archaic DOS operating system:

“The 640KB of RAM that once seemed so luxurious is now choked with contentious device drivers and TSR programs. IRQs (interrupt requests), DMA channels, I/O memory ports, and other system resources are now being fought over like the last pebbles of ore in a played-out gold mine”. (Halfhill, 1994)[3]

Adaptor card timing problems can also cause much slot swapping and a rapidly growing collection of mutually exclusive cards. The Apple Macintosh and the Acorn 32-bit RISC computers do not suffer from any such problems: the systems were designed from the ground-up with a more efficient and extensible combined operating system and GUI.

The Computer History Museum has an excellent tribute to Steve Jobs and Apple, including this rare 1980 footage in which he describes the early days of the company.
http://www.computerhistory.org/highlights/stevejobs/video/

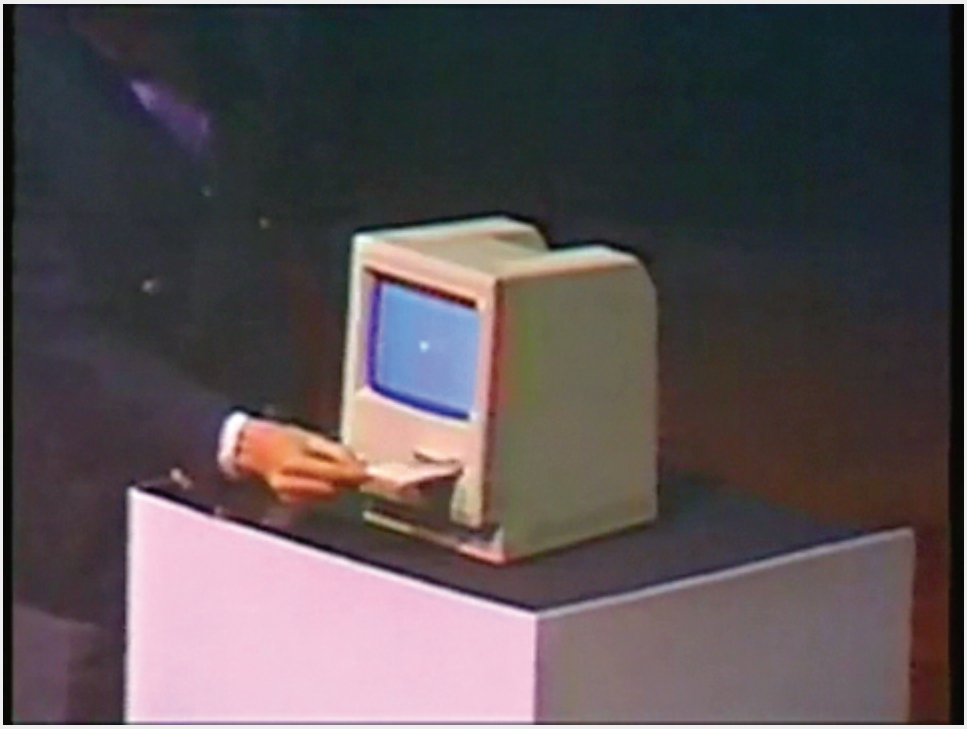
Steve Jobs talks about NeXT (1987)
http://www.youtube.com/watch?v=WHsHKzYOV2E

3. Halfhill, Tom R. Apple's Technology Milestones, Byte Magazine, December 1994, pp 52-60.

In 1984, Steve Jobs contributed an essay that originally appeared on page 135 of the first issue of Macworld.

> The people who are doing the work are the moving force behind the Macintosh. My job is to create a space for them, to clear out the rest of the organization and keep it at bay. I can't spend enough time here, unfortunately, because I have other responsibilities. But every spare moment I have, I dash back because this is the most fun place in the world.
>
> This is the neatest group of people I've ever worked with. They're all exceptionally bright, but more importantly they share a quality about the way they look at life, which is that the journey is the reward. They really want to see this product out in the world. It's more important than their personal lives right now.
>
> The Apple II had a magical feel about it. You couldn't quantify it, but you could tell. The Macintosh is the second thing in my life that's ever felt that way. Opportunities like this don't come along very often. You know somehow that it's the start of something great. So everyone wants it to be perfect and works really hard on it. Everyone feels a personal responsibility for the product.
>
> The Macintosh is the future of Apple Computer. And it's being done by a bunch of people who are incredibly talented but who in most organizations would be working three levels below the impact of the decisions they're making in the organization. It's one of those things that you know won't last forever. The group might stay together maybe for one more iteration of the product, and then they'll go their separate ways. For a very special moment, all of us have come together to make this new product. We feel this may be the best thing we'll ever do with our lives.

Movie 16.4 Steve Jobs Introduces Macintosh



The Original 1984 Macintosh Introduction: the magic moment, when Steve Jobs unveils the Macintosh and releases it from its bag. http://www.youtube.com/watch?v=2B-XwPjn9YY

Movie 16.5 Gates and Jobs together



Bill Gates and Steve Jobs appeared on stage together at the D5 All Things Digital event in 2007.
https://www.youtube.com/watch?v=P_5xhcpoeoM

This sequence is the opening video of the discussion, which can be seen in its full (1 hour and 30 minutes) entirety at
http://www.youtube.com/watch?v=ZWaX1g_2SSQ

Movie 16.6 Gates/Jobs Rivalry



Steve Jobs Biographer Walter Isaacson chronicles the tumultuous relationship between the two tech giants dating back to the 1970s.
https://www.youtube.com/watch?v=1Bk-qTzN7vE

The first Macintosh had no network capabilities, and when asked about it, Steve Jobs reportedly threw a floppy disc at a journalist, saying “Here’s my network”.

16.3 The IBM PC and Unix



The IBM PC was introduced in 1981, impacting the business world in ways that were dramatic. First, it caused other companies, including Apple, to take a new look at how the computer and the GUI could have an impact even beyond the personal computing arena. The PC ultimately impacted many of the decisions that resulted in the introduction of the Macintosh.



The IBM 5100 weighed over 50 pounds. It was marketed from 1975-1982

In the mid 1970s the IBM company was split into independent business units, including one called the Entry Level Systems (ELS) group. They were responsible for the design of new machines that would advance the IBM brand, within the “affordable” market. The group introduced the IBM 5100 Desktop Portable in 1975 and the 5120 in 1980. These platforms were used as data collection and analysis systems for small labs, and the 5100 had an integrated CRT, keyboard, and tape drive. It was capable of emulating IBM mainframe software. The 5120 was a larger, more expandable version of the 5100.

Intel introduced the first commercial microprocessor in 1971, the Intel 4004, and a few years later introduce the 8008. Altair used the microprocessor in its hobbyist-focused Altair 8800, released in 1975. At the same time, software markets started to open up, thanks to programmers at companies like Digital Research, which sold the CP/M operating system and several programming languages.



January 1975 Cover

The success of the Altair got IBM executives and other computer companies thinking about how they could play in this evolving market. IBM in particular started plans for introducing an IBM microcomputer aimed towards small businesses and consumers. They designed a prototype, based on the Intel 8088 16-bit processor. The software development team for the prototype wanted to make certain that appropriate and necessary operating systems, compilers and software could be available in a timely fashion, so they looked to outsourcing the development. Enter the independent company Microsoft, the market leader in programming languages. Using emulation software running on a DEC minicomputer, Microsoft ported its version of BASIC to the 8088. The project, codenamed Project Chess, presented the prototype, internally called Acorn, to IBM management, showing it running CP/M and using the newly created MBASIC.

Because of disagreements between IBM and the CP/M team, IBM chose to develop a different OS, so they again contacted Microsoft to develop an OS and programming language for Acorn.



IBM PC/XT

The new PC computer, which the marketing staff wanted to price at $1,565, required a different approach to marketing than the approach normally taken by IBM for their larger and more costly machines. It was to be sold to individuals, and IBM wanted to use consumer electronics stores and department stores to sell the new computer, bypassing the normal IBM sales staff.

The marketing campaign used Charlie Chaplin, and was very effective in reaching the desired customer base. The Acorn was renamed the IBM PC 5150, or IBM PC.



Charlie Chaplin

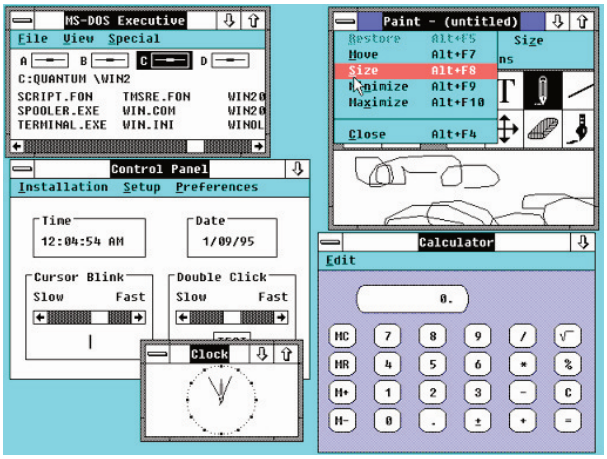
In the meantime, the Microsoft partnership was beginning to take shape. Microsoft bought an operating system called QDOS (for quick and dirty operating system) that ran on the 8088 processor from programmer Tim Patterson, who had previously developed it as a port of CP/M. IBM agreed to use QDOS, but renamed it PC-DOS, and let Microsoft market its own version, which they called MS-DOS, leading to the creation of a clone industry a few years later. If MS-DOS hadn't been freely available, there wouldn't have been a huge market of commodity computers that were capable of running Windows. In short, Microsoft really owes its entire success to the IBM PC and the PC clones.

In addition to PC-DOS, the programs VisiCalc and EasyWriter were bundled with the PC, although the first version of EastWriter was not very dependable.

IBM's sales went beyond expectations the first two years, as they sold nearly 3/4 of a million units, tripling the marketing goals.

The IBM PC was more popular with businesses than the Mac, even though it didn't have a GUI. **Bill Gates** and Microsoft began developing useful applications for the Mac which helped increase sales. Microsoft's early partnership with Apple allowed them access to the Mac OS which led to the development of their own GUI, Windows 1.0. Microsoft saw the Mac OS as a threat to their non-graphical operating systems for IBM PCs, MS DOS and knew that they had to develop a GUI to compete.

Steve Jobs had quoted a saying of Picasso that "good artists borrow, but great artists steal" in describing what the Macintosh had gotten from Xerox PARC. Microsoft might say the same about what they got from Apple. In November of 1985, Microsoft's Bill Gates showed Windows at COMDEX. Windows appeared to copy many of the same metaphors and icons as the Mac GUI with just the names changed, for example the Trash Can in Mac, became the Recycle Bin in Windows (and later the Dumpster in X-Windows for SGI Workstations).



Windows 2.0 screen

Apple objected and threatened to sue Microsoft, and Gates became very angry over the threat. Ultimately the two companies came to an agreement, and Apple agreed to license the Macintosh's "visual displays" to Microsoft to use in software derived from Windows 1.0. Microsoft agreed to continue developing its Mac products. They also proceeded to develop Windows 2.0, which they released in November of 1987.

Apple's executives felt that this version was a breach of the contract that was signed earlier, given how much Windows 2.0 resembled the Macintosh GUI. Apple filed suit against Microsoft in federal court on March 17, 1988 for violating Apple's copyright, and Microsoft countersued. However, the judge in the case ruled in Microsoft's favor that most of the contested violations were not in fact violations of Apple's copyright due to the fact that ideas cannot be protected by copyright.

The relationship between the companies was strained for decades, as Apple appealed the ruling. The case made it all the way to the Supreme Court, which declined to hear the arguments. Online author Tom Hornby has an excellent series of articles on the Mac/PC history, including the Apple/Microsoft lawsuit at *http://lowendmac.com/orchard/06/apple-vs-microsoft.html*

Windows became more popular not because it was better than the Mac OS, but because it was more open, and could run on millions of IBM PCs and Mac Clones. Apple never licensed the Mac OS to clone makers except for a brief period in the mid 1990s. This caused Apple to lose market share, but kept the quality of their product more consistent than with IBM clones. Windows had flaws because it was built on top of the non-GUI MS-DOS, and it would behave differently on each type of PC clone.

In 1986 Steve Jobs left Apple after disagreements with the board of directors and founded a new company called NeXT which would develop NeXTStep, a GUI for it's Unix based workstations in 1988. This became the first GUI to simulate a three-dimensional screen. Later when Steve Jobs returned to Apple, NeXTStep would merge with the Mac OS to create Mac Os X.

Around the same time as NeXTStep, in the late 1980s, other Unix workstation manufactures wanted a piece of the GUI action. In 1987 the X Windows System for Unix workstations became widely available. Around 1989 several Unix-based GUIs were introduced. These included Open Look, by AT&T and Sun Microsystems, and Motif for the Open Software Foundation by DEC and Hewlett-Packard. Motif's appearance is based on IBM's Presentation Manager, a rival GUI to MS Windows.

16.4 Amiga



Although the Macintosh and the PC were the two most important personal computer contributors to the graphics area, they were certainly not the only personal computers that impacted the market. Atari, Tandy, and Commodore all developed computers that helped push the success of the home or personal computer revolution.Of these, from a graphics standpoint, arguably the most influential computer was the Amiga.

By the end of the 1970s, the Apple II, the Tandy TRS-80 (Trash-80), and the Atari computers were available on the market, and Commodore was marketing the PET, or Personal Electronic Transactor. They used 8-bit processors, like the MOS 6502 and the Zilog80. In each case, the graphics capabilities were primitive. For example, the Apple II video controller displayed 24 lines by 40 columns of upper-case-only text on the screen, with NTSC composite video output for display on a monitor, or on a TV set by way of an RF modulator. There needed to be better graphics capabilities for these products to be as successful as their potential showed.



TRS-80



Commodore Pet

Jay Miner started working at Atari in the late 1970s. He was instrumental in pushing the capabilities of the electronics by combining the necessary components into a single chip, known as the TIA, or Television Interface Adaptor. The TIA was to become the display hardware for the Atari 2600 game console, and was the forerunner to the chip set which was the basis of the Atari 8-bit family of home computers, known as ANTIC and GTIA.



Lorraine Concept – Courtesy of Secret Weapons of Commodore

In the early 1980s Jay, along with other Atari staffers, had become disillusioned with management and started a new company in Santa Clara, called Hi-Toro. They worked on a new 16-bit (Motorola 68000 based) game console. This project, which then was code-named Lorraine, resulted in a design that could be upgraded to a full-fledged computer. Commodore International assumed ownership of Hi-Toro. It was at this time that the video-game market was beginning to fail, so the new owners began changing Lorraine's design to become a home computer, the Amiga.

Jack Tramiel invested $500,000 in the Amiga Lorraine project, hoping to use the results of their development for a series of 32-bit machines that would replace Atari's existing home computer line. As Amiga's financial health got worse, Commodore took over the entire Amiga staff and the Lorraine project, just before Tramiel could assume ownership. He subsequently sued Amiga for fraud in the matter of the development of the three VLSI chips, which Amiga alleged didn't work, canceling the deal. Tramiel felt that the chips did work, and were going to be part of a the new Commodore computer.

In June 1985 the first production of an Amiga, the A1000 began. It had 256K RAM, which was later updated to 512K as standard which was enormous for its time. It also had a previously unknown 4096 color palette, and had a 14MHz Motorola 68000 processor. It also allowed direct to video tape recording with its integrated composite video output connection. The Amiga 1000 could have been a serious competitor to IBM's PC, but Commodore focused it specifically for home use, primarily as a replacement for the Commodore 64.

In 1986 Amiga's engineers started to design the A2000. This was to be the replacement to the A1000, with a bigger box, more expansion capabilities and an updated OS. The A2000 (and its cheaper version the A500) were released in 1987. The A500 had only one expansion slot and a single memory-upgrade slot, and became the single most popular Amiga ever.



a500



a2000

For its time, the Amiga had some of the most impressive sound and graphics (through several coprocessors) available for the home user. It was also used for commercial entertainment production during the 1980s. Newtek marketed a special graphics rendering solution of the Amiga, called the Video Toaster. (The Video Toaster was used to render the space ships in the first season of *Babylon 5*). NewTek also created the Lightwave 3D rendering program on the Amiga, which they eventually ported to the PC. The support of overscan, interlacing and **genlocking** capabilities, and the fact that the display timing was very close to broadcast standards (NTSC or PAL), made the Amiga the ideal computer for video purposes, and was used in many studios for digitizing video data (sometimes called **frame-grabbing**), subtitling and interactive video news.

The chipset which gave the Amiga its unique graphics features consisted of three custom chips, OCS, ECS and AGA, nicknamed Agnus, Daphne (Denise), and Paula (Portia). Daphne was basically a non-programmable chip responsible for transferring the raw bit data through a hybrid integrated circuit to the RGB port. Paula was a sound chip that allowed 4 channel hardware DMA driven stereo output.

Agnus took care of the multimedia capabilities, providing DMA for sound and graphics, handling memory, and performing video timing (PAL or NTSC versions). The video timings were deliberately chosen to make it possible to use the Amiga with common household TV sets, and the Amiga had output ports for monochrome video signal, and separate RGB monitor connections.

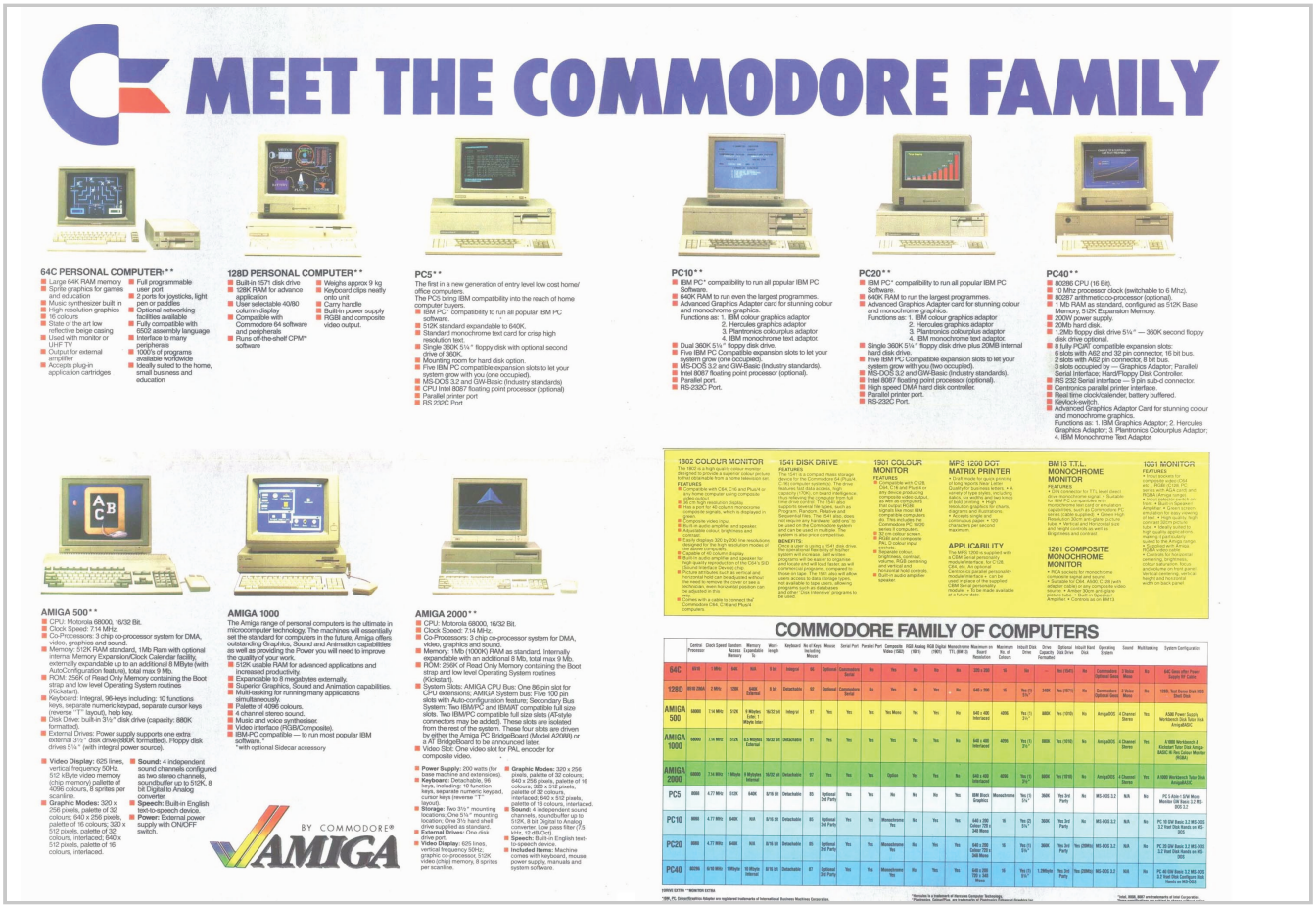
A newer version of Agnus (used in most of the A500 and A2000 computers) was called Fat Agnus. It could handle a full megabyte of RAM. (Super Agnus, an even more recent version was able to support 2 MB RAM, and was able to change between PAL and NTSC video signal timing.)

The basic resolution of an Amiga display (sometimes called LoRes for low resolution) was 320×200 by 60 Hz (NTSC timing), or 320×256 by 50 Hz (PAL timing). In these resolutions, it was able to display 2, 4, 8, 16 or 32 colors in a palette based manner simultaneously from 4096 colors (4 bit for each of the RGB components).

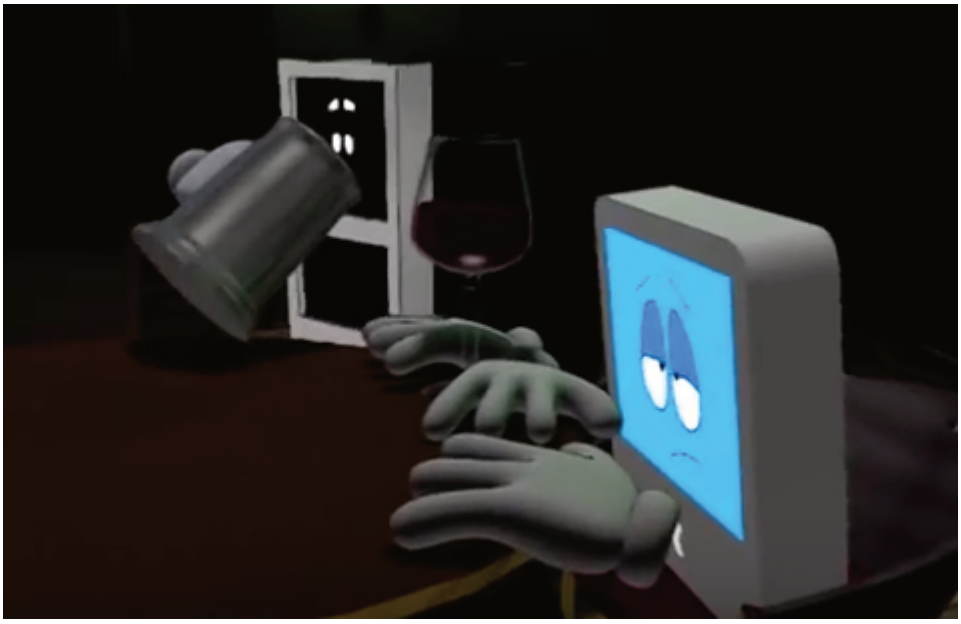
The number of colors on screen could also be increased:

- EHB, or Extended HalfBright – an additional bit plane was used to display 64 colors, but the second 32 colors were half the brightness of the first 32.
- HAM, or Hold-And-Modify, where six bit planes were used, but only 16 colors were defined by the palette; the remaining 48 “colors” described how to modify the previous pixel color.
- A special mode existed (mainly used for games) called dual playfield mode, where two screens of maximum 8 colors were behind each other. One of the colors in the front screen was disabled and changed to transparent (for pixels having this color the other screen is visible).

The Amiga included a hardware BitBLt co-processor, which was used to create and move several dozen additional objects in the bit map each frame time, saving and restoring the background as necessary. The “Blitter”also provided hardware support for line drawing and polygon filling functions. The operating system, AmigaOS, was quite sophisticated, combining an elegant GUI like that of the Apple Macintosh with some of the flexibility of UNIX while retaining a simplicity that made maintenance rather easy. The Copper processor was a 3 instruction co-processor running in parallel with main CPU, allowing for the creation graphics effects with minimal CPU load and intervention.



Movie 16.7 Only Amiga!



Eric Schwartz animated tribute to the Amiga on its 25th anniversary
https://www.youtube.com/watch?v=iNR5vxAR22A

Movie 16.8 Revolution: Amiga and Toaster



1991 demo of the Amiga and the Newtek Video Toaster card
https://www.youtube.com/watch?v=seznQmDp2pU

16.5 Timeline of the GUI

The following timeline can be traversed by moving the slider from left to right. Each blue dot is another selection.

Note: Original *As We May Think* article, by Vannevar Bush, is in the Atlantic Monthly archives.

Chapter 17: Virtual Environments

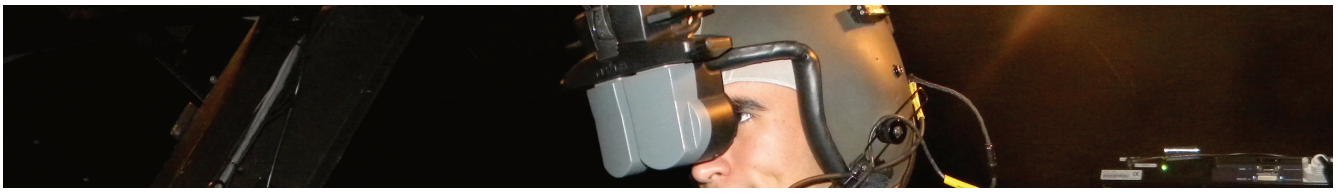
Virtual Environments

> “Artificial life, a major subfield of complexity studies, is ‘fact-free science’, but it excels at generating computer graphics.”
>
> *John Maynard Smith, Evolutionary theorist*



Virtual Reality Laboratory at the Johnson Space Center, NASA (2011)

17.1 Virtual Reality



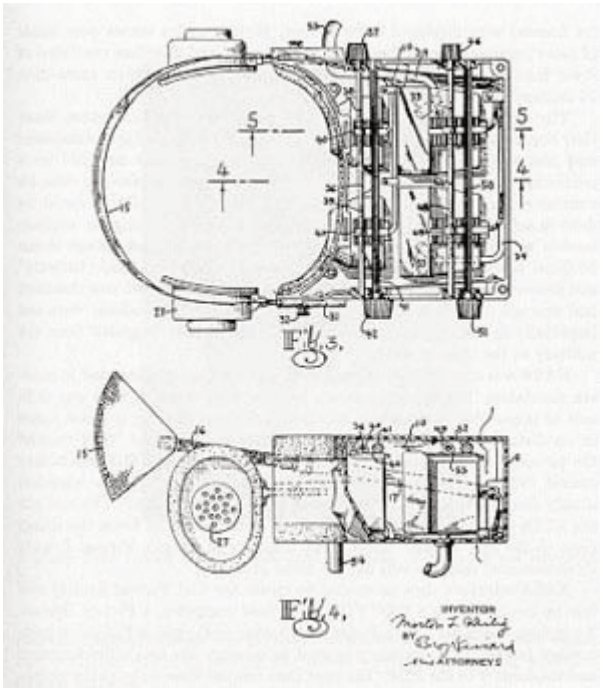
During the late 1980s and 1990s, virtual reality was touted as a new and emerging application that promised to revolutionize interactivity and man-computer interfaces. In fact, VR is much older than the 1980s, older or nearly as old as the entire computer graphics field itself.



The Sensorama Machine was invented in 1957

In 1956, Morton Heilig began designing the first multi-sensory virtual experiences. Resembling one of today's arcade machines, the Sensorama combined projected film, audio, vibration, wind, and odors, all designed to make the user feel as if he were actually in the film rather than simply watching it. Patented in 1961, the Sensorama placed the viewer in a one person theater and, for a quarter, the viewer could experience one of five two-minute 3D full color films with ancillary sensations of motion, sound, wind in the face and smells. The five "experiences" included a motorcycle ride through New York, a bicycle ride, a ride on a dune buggy, a helicopter ride over Century city in 1960 and a dance by a belly dancer. Since real-time computer graphics were many years away, the entire experience was prerecorded, and played back for the user.

Heilig also patented an idea for a device that some consider the first Head-Mounted Display (HMD). He first proposed the idea in 1960 and applied for a patent in 1962. It used wide field of view optics to view 3D photographic slides, and had stereo sound and an "odor generator". He later proposed an idea for an immersive theater that would permit the projection of three dimensional images without requiring the viewer to wear special glasses or other devices. The audience would be seated in tiers and the seats would be connected with the film track to provide not only stereographic sound, but also the sensation of motion. Smells would be created by injecting various odors into the air conditioning system. Unfortunately, Heilig's "full experience" theater was never built.



Helig's HMD

Comeau and Bryan, employees of Philco Corporation, constructed the first actual fabricated head-mounted display in 1961. Their system, called Headsight featured a single CRT element attached to the helmet and a magnetic tracking system to determine the direction of the head. The HMD was designed to be used with a remote controlled closed circuit video system for remotely viewing dangerous situations. While these devices contributed intellectual ideas for display and virtual experiences, the computer and image generation were yet to be integrated.

The field we now know as **virtual reality** (VR), a highly multidisciplinary field of computing, emerged from research on three-dimensional interactive graphics and vehicle simulation in the 1960s and 1970s. Not surprisingly, the development of the discipline can be traced to early work at MIT and Utah and none other than Ivan Sutherland.

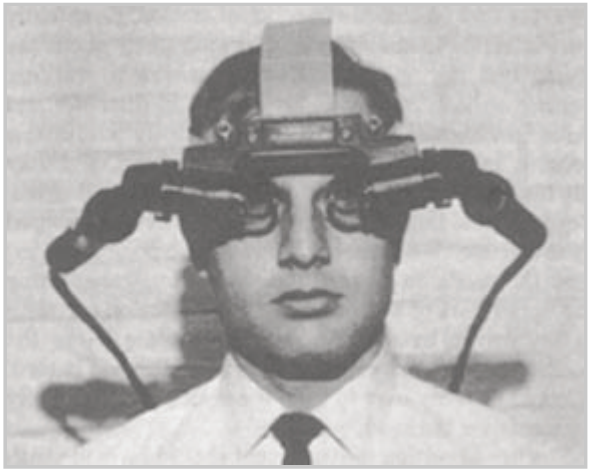
Two of the necessary foundations of VR were being addressed at MIT by Larry Roberts and Sutherland, among others. The first necessary practical contributions included the research and development that allowed the CRT to serve as an affordable and effective device on which to create a computer generated image, and the interactive interfaces that showed that a user could interact with the CRT image to accomplish some desired task.

As we mentioned in Chapter 4, Roberts wrote the first algorithm to eliminate hidden or obscured surfaces from a perspective picture in 1963. His solutions to this and other related problems prompted attempts over the next decade to find faster algorithms for generating hidden surfaces. Among the important activities of Sutherland and his colleagues and students at the University of Utah were efforts to develop fast algorithms for removing **hidden surfaces** from 3D graphics images, a problem identified as a key computational bottleneck.

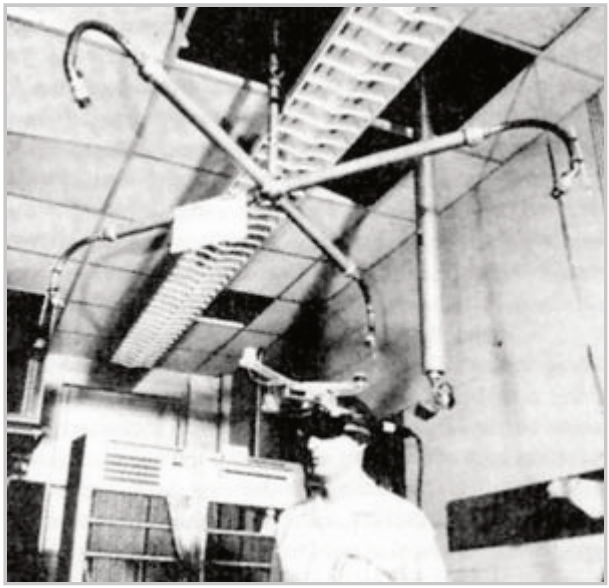
Students of the Utah program made two important contributions in this field, including an area search method by Warnock (1969) and a scan-line algorithm that was developed by Watkins (1970) and developed into a hardware system. One of the most important breakthroughs was Henri Gouraud's development of a simple scheme for continuous shading (1971). Unlike polygonal shading, in which an entire polygon (a standard surface representation) was a single level of gray, Gouraud's scheme involved interpolation between points on a surface to

describe **continuous shading** across a single polygon, thus achieving a closer approximation of reality. The effect made a surface composed of discrete polygons appear to be continuous. This ability is essential in the process of generating the quality of visual images necessary to present a believable VR environment.





HMD images from Sutherland's AFIPS and FJCC papers



The mechanical head position sensor



The ultrasonic head position sensor

Each of these efforts provided part of the foundation for early attempts at addressing the concept of a virtual environment. The other part was the earlier work that resulted in the commercial development of the important head mounted display. The Ultimate Display was created by Sutherland in 1965. What made it so important was the fact that it had a **stereoscopic display** (one CRT element for each eye). The HMD had a mechanical tracking system, and later Sutherland experimented with an ultrasonic tracker. As was discussed in the National Academy of Sciences report *Funding a Revolution: Government Support for Computing Research*, the HMD was the central research component of the emerging field. The following text, from this report, outlines the important work in this area:

Work on **head-mounted displays** (HMDs) illustrates the synergy between the applications-focused environments of industry and government-funded (both military and civilian) projects and the fundamental research focus of university work that spills across disciplinary boundaries. Work on head-mounted displays benefited from extensive interaction and cross-fertilization of ideas among federally funded, mission-oriented military projects and contracts as well as private-sector initiatives. The players included NASA Ames, Armstrong Aerospace Medical Research Laboratory of the Air Force, Wright-Patterson Air Force Base, and, more recently, DOD programs on modeling and simulation, such as the Synthetic Theater of War program. Each of these projects generated a stream of published papers, technical reports, software (some of which became commercially available), computer-animated films, and even hardware that was accessible to other graphics researchers. Other important ideas for the head-mounted display came from Knowlton and Schroeder's work at Bell Laboratories, the approach to real-time hidden-line solutions by the MAGI group, and the GE simulator project (Sutherland, 1968).

Early work on head-mounted displays took place at Bell Helicopter Company. Designed to be worn by pilots, the Bell display received input from a servo-controlled infrared camera, which was mounted on the bottom of a helicopter. The camera moved as the pilot's head moved, and the pilot's field of view was the same as the camera's. This system was intended to give military helicopter pilots the capability to land at night in rough terrain. The helicopter experiments demonstrated that a human could become totally immersed in a remote environment through the eyes of a camera.

The power of this immersive technology was demonstrated in an example cited by Sutherland (1968). A camera was mounted on the roof of a building, with its field of view focused on two persons playing catch. The head-mounted display was worn by a viewer inside the building, who followed the motion of the ball, moving the camera by using head movements. Suddenly, the ball was thrown at the camera (on the roof), and the viewer (inside the building) ducked. When the camera panned the horizon, the viewer reported seeing a

panoramic skyline. When the camera looked down to reveal that it was “standing” on a plank extended off the roof of the building, the viewer panicked!

In 1966, Ivan Sutherland moved from ARPA to Harvard University as an associate professor in applied mathematics. At ARPA, Sutherland had helped implement J.C.R. Licklider’s vision of human-computer interaction, and he returned to academe to pursue his own efforts to extend human capabilities. Sutherland and a student, Robert Sproull, turned the “remote reality” vision systems of the Bell Helicopter project into VR by replacing the camera with computer-generated images.(Other head-mounted display projects using a television camera system were undertaken by Philco in the early 1960s, as discussed by Ellis in 1996.) The first such computer environment was no more than a wire-frame room with the cardinal directions–north, south, east, and west–initialed on the walls. The viewer could “enter” the room by way of the “west” door and turn to look out windows in the other three directions. What was then called the head-mounted display later became known as VR.

Sutherland’s experiments built on the network of personal and professional contacts he had developed at MIT and ARPA. Funding for Sutherland’s project came from a variety of military, academic, and industry sources. The Central Intelligence Agency provided $80,000, and additional funding was provided by ARPA, the Office of Naval Research, and Bell Laboratories. Equipment was provided by Bell Helicopter. A PDP-1 computer was provided by the Air Force and an ultrasonic head-position acoustic sensor was provided by MIT Lincoln Laboratory, also under an ARPA contract.

Sutherland outlined a number of forms of interactive graphics that later became popular, including **augmented reality**, in which synthetic, computer-generated images are superimposed on a realistic image of a scene. He used this form of VR in attempting a practical medical application of the head-mounted display. The first published research project deploying the 3D display addressed problems of representing hemodynamic flow in models of prosthetic heart valves. The idea was to generate the results of calculations involving physical laws of fluid mechanics and a variety of numerical analysis techniques to generate a synthetic object that one could walk toward and move into or around (Greenfield, Harvey, Donald Vickers, Ivan Sutherland, Willem Kolff, et al. 1971. “Moving Computer Graphic Images Seen from Inside the Vascular System,” Transactions of the American Society of Artificial Internal Organs, 17:381-385.)

As Sutherland later recalled, there was clearly no chance of immediately realizing his initial vision for the head-mounted display. Still, he viewed the project as an important “attention focuser” that “defined a set of problems that motivated people for a number of years.” Even though VR was impossible at the time, it provided “a reason to go forward and push the technology as hard as you could. Spin-offs from that kind of pursuit are its greatest value.” ?(Ivan Sutherland in Virtual Reality Before It Had That Name, a videotaped lecture before the Bay Area Computer History Association.)

http://www.nap.edu/readingroom/books/far/contents.html

VR is one of those fields that Ivan Sutherland would christen “holy grails” – fields involving the synthesis of many separate, expensive, and risky lines of innovation in a future too far distant and with returns too unpredictable to justify the long-term investment.

Sutherland (1965) The Ultimate Display

The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such room would be fatal. With appropriate programming such a display could literally be the Wonderland into which Alice walked.

The actual term "Virtual Reality" is attributed to Jaron Lanier of VPL in 1986 in a conversation regarding the work of Scott Fisher. Fisher, of NASA Ames, had been referring to the field as "Virtual Environments".

Myron Krueger labeled the activity "Artificial Reality" in 1983, the title of his book, and a year later, William Gibson coined the term "Cyberspace" in his book Neuromancer.
https://www.theguardian.com/books/2011/sep/22/william-gibson-beyond-cyberspace

> Virtual Reality — a three dimensional, computer generated simulation in which one can navigate around, interact with, and be immersed in another environment
> (John Briggs – The Futurist)
>
> Virtual Reality — the use of computer technology to create the effect of an interactive three-dimensional world in which the objects have a sense of spatial presence.
> (Steve Bryson – NASA Ames)

Heilig's head mounted display from his patent application
http://www.mortonheilig.com/TelesphereMask.pdf

"The Ultimate Display," Sutherland, I.E., Proceedings of IFIPS Congress 1965, New York, May 1965, Vol. 2, pp. 506-508. ?(reprinted in Wired's "Beyond the Beyond")

Sutherland, Ivan E. 1968. "A Head-Mounted Three Dimensional Display," pp. 757-764 in Proceedings of the Fall Joint Computer Conference. AFIPS Press, Montvale, N.J.

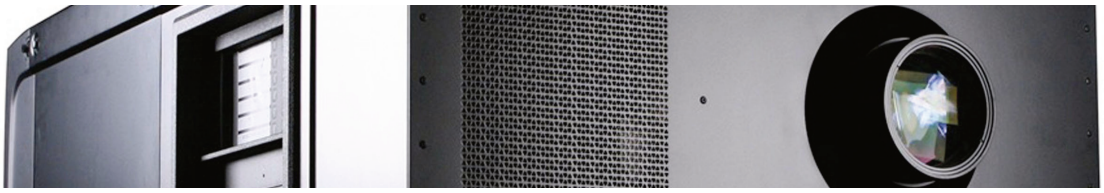
Ellis, S. What are Virtual Environments? IEEE Computer Graphics & Applications.

Ellis, S. (1996). Virtual Environments and Environmental Instruments, In Simulated and Virtual Realities, Taylor & Francis: 1996.

Furness, T. 1986. The super cockpit and its human factors challenges. Proceedings of the Human Factors Society. 30, 48-52.

An interview with Tom Furness: 50 years of VR with Tom Furness: The Super Cockpit, Virtual Retinal Display, HIT Lab, & Virtual World Society

17.2 Virtual Projection



Around the same time, Thomas A. Furness, a scientist at Wright-Patterson Air Force Base in Ohio, began to work on better cockpit technology for pilots. “I was trying to solve problems of how humans interact with very complex machines,” said Furness. “In this case, I was concerned with fighter-airplane cockpits.” Aircraft were becoming so complicated that the amount of information a fighter pilot had to assimilate from the cockpit’s instruments and command communications had become overwhelming. The solution was a cockpit that fed 3-D sensory information directly to the pilot, who could then fly by nodding and pointing his way through a simulated landscape below. Today, such technology is critical for air wars that are waged mainly at night, since virtual reality replaces what a pilot can’t see with his eyes.

“To design a virtual cockpit, we created a very wide field of vision,” said Furness, who now directs the *University of Washington’s Human Interface Technology (HIT) Lab*. “About 120 degrees of view on the horizontal as opposed to 60 degrees.” In September of 1981, Furness and his team turned on the virtual-cockpit projector for the first time. “I felt like Alexander Graham Bell, demonstrating the telephone,” recalled Furness. “We had no idea of the full effect of a wide-angle view display. Until then, we had been on the outside, looking at a picture. Suddenly, it was as if someone reached out and pulled us inside.”

The Human Interface Technology Laboratory is a research and development lab in virtual interface technology. HITL was established in 1989 by the Washington Technology Center (WTC) to transform virtual environment concepts and early research into practical, market-driven products and processes. HITL research strengths include interface hardware, virtual environments software, and human factors.

While multi-million dollar military systems have used head-mounted displays in the years since Sutherland’s work, the notion of a personal virtual environment system as a general purpose user-computer interface was generally neglected for almost twenty years. Beginning in 1984, Michael McGreevy created the first of NASA’s virtual environment workstations (also known as personal simulators and Virtual Reality systems) for use in human-computer interface research. With contractors Jim Humphries, Saim Eriskin and Joe Deardon, he designed and built the Virtual Visual Environment Display system (VIVED, pronounced “vivid”), the first low-cost, wide

field-of-view, stereo, head-tracked, head-mounted display. Clones of this design, and extensions of it, are still predominant in the VR market.

Next, McGreevy configured the workstation hardware: a Digital Equipment Corporation PDP-11/40 computer, an Evans and Sutherland Picture System 2 with two 19″ monitors, a Polhemus head and hand tracker, video cameras, custom video circuitry, and the VIVED system. With Amy Wu, McGreevy wrote the software for NASA's first virtual environment workstation. The first demonstrations of this Virtual Reality system at NASA were conducted by McGreevy in early 1985 for local researchers and managers, as well as visitors from universities, industry, and the military. Since that time, over two dozen technical contributors at NASA Ames have worked to develop Virtual Reality for applications including planetary terrain exploration, computational fluid dynamics, and space station telerobotics. In October 1987 Scientific American featured VIVED – a minimal system, but one which demonstrated that a cheap immersive system was possible.



Scientific American issue on VR

17.3 Hypermedia and Art



In 1978 Andy Lippman and group of researchers from MIT (including Michael Naimark and Scott Fisher) developed what is probably the first true hypermedia system. The Aspen Movie Map was what they termed “a surrogate travel application” that allowed the user to enjoy a simulated ride through the city of Aspen, Colorado.



Scene from Aspen Movie Map

The system used a set of videodisks containing photographs of all the streets of Aspen. Recording was done by means of four cameras, each pointing in a different direction, and mounted on a truck. Photo’s were taken every 3 meters. The user could always continue straight ahead, back up, move left or right.

Each photo was linked to the other relevant photos for supporting these movements. In theory the system could display 30 images per second, simulating a speed of 200 mph (330 km/h). The system was artificially slowed down to at most 10 images per second, or 68 mph (110 km/h).

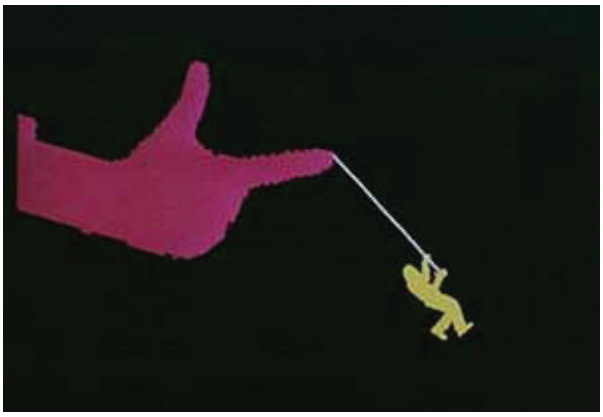
Movie 17.1 Aspen Map example



https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/aspen-map-1.m4v

To make the demo more lively, the user could stop in front of some of the major buildings of Aspen and walk inside. Many buildings had also been filmed inside for the videodisk. The system used two screens, a vertical one for the video and a horizontal one that showed the street map of Aspen. The user could point to a spot on the map and jump directly to it instead of finding her way through the city.

Working on human-computer interaction at the University of Wisconsin in the late 1960s and early 1970s, **Myron Krueger** experimented and developed several computer art projects.



Scene from VIDEOPLACE

After several other experiments, VIDEOPLACE was created. The computer had control over the relationship between the participant's image and the objects in the graphic scene, and it could coordinate the movement of a graphic object with the actions of the participant. While gravity affected the physical body, it didn't control or confine the image which could float, if needed. A series of simulations could be programmed based on any action. VIDEOPLACE offered over 50 compositions and interactions (including Critter, Individual Medley, Fractal, Finger Painting, Digital Drawing, Body Surfacing, Replay, and others).

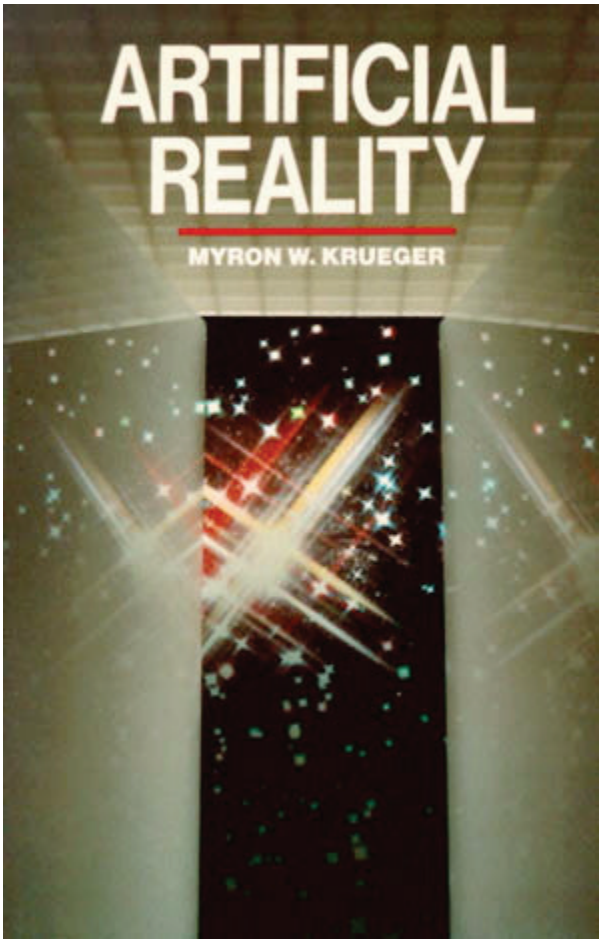
In the installation, the participant faced a video-projection screen while the screen behind him was backlit to produce high contrast images for the camera (in front of the projection screen), allowing the computer to distinguish the participant from the background.



VIDEOPLACE configuration

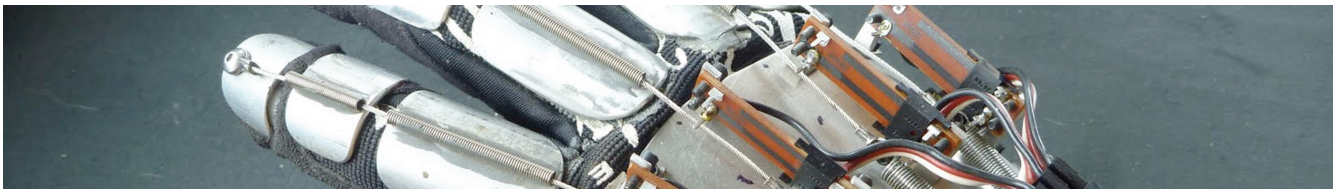
The participant's image was then digitized to create silhouettes which were analyzed by specialized processors. The processors could analyze the image's posture, rate of movement, and its relationship to other graphic objects in the system. They could then react to the movement of the participant and create a series of responses, either visual or auditory reactions. Two or more environments could also be linked.

In 1983 Krueger published his now-famous book Artificial Reality, which was updated in 1990.

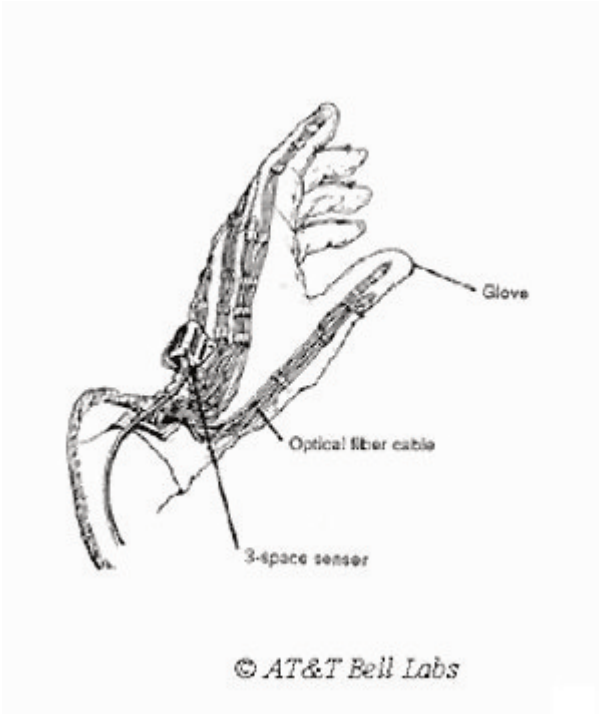


Krueger, M.W., "Artificial Reality" ?Reading, Mass., Addison Wesley, 1983

17.4 Interaction



One of the first instrumented gloves described in the literature was the Sayre Glove, developed by Tom Defanti and Daniel Sandin in a 1977 project for the National Endowment for the Arts. (In 1962 Uttal from IBM patented a glove for teaching touch typing, but it was not general purpose enough to be used in VR applications.) The Sayre glove used light based sensors with flexible tubes with a light source at one end and a photocell at the other. As the fingers were bent, the amount of light that hit the photocells varied, thus providing a measure of finger flexion. The glove, based on an idea by colleague Rich Sayre, was an inexpensive, lightweight glove that could monitor hand movements by measuring the metacarpophalangeal joints of the hand. It provided an effective method for multidimensional control, such as mimicking a set of sliders.



Grimes Glove

The first widely recognized device for measuring hand positions was developed by Dr. Gary Grimes at Bell Labs. Patented in 1983, Grimes' Digital Data Entry Glove had finger flex sensors, tactile sensors at the fingertips, orientation sensing and wrist-positioning sensors. The positions of the sensors themselves were changeable. It was intended for creating "alpha-numeric" characters by examining hand positions. It was primarily designed as an alternative to keyboards, but it also proved to be effective as a tool for allowing non-vocal users to "finger-spell" words using such a system.

This was soon followed by an optical glove, which was later to become the VPL DataGlove. This glove was built by Thomas Zimmerman, who also patented the optical flex sensors used by the gloves. Like the Sayre glove, these sensors had fibre optic cables with a light at one end, and a photodiode at the other. Zimmerman had also built a simplified version, called the Z-glove, which he had attached to his Commodore 64. This device measured the angles of each of the first two knuckles of the fingers using the fibre optic devices, and was usually combined with a Polhemus tracking device. Some also had abduction measurements. This was really the first commercially available glove, however at about $9000 was prohibitively expensive.

The Dataglove (originally developed by VPL Research) was a neoprene fabric glove with two fiber optic loops on each finger. Each loop was dedicated to one knuckle, which occasionally caused a problem. If a user had extra large or small hands, the loops would not correspond very well to the actual knuckle position and the user was not able to produce very accurate gestures. At one end of each loop was an LED and at the other end a photosensor. The fiber optic cable had small cuts along its length. When the user bent a finger, light escaped from the fiber optic cable through these cuts. The amount of light reaching the photosensor was measured and converted into a measure of how much the finger was bent. The Dataglove required recalibration for each user, and often for the same user over a session's duration. Coupled with a problem of fatigue (because of the stiffness) it failed to reach the market penetration that was anticipated.



VPL DataGlove



Source: NASA

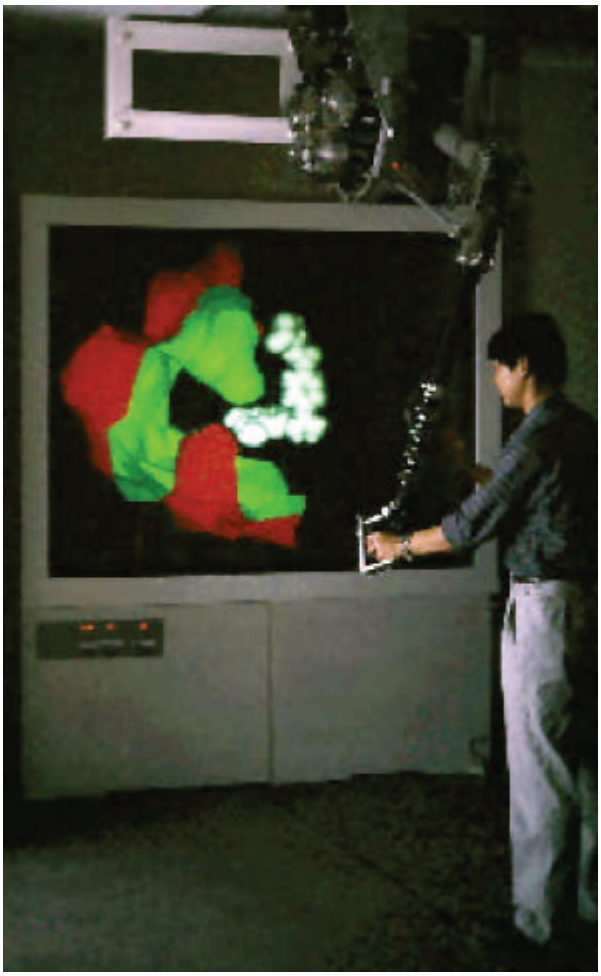
Again from the National Academy of Sciences report:

> The basic technologies developed through VR research have been applied in a variety of ways over the last several decades. One line of work led to applications of VR in biochemistry and medicine. This work began in the 1960s at the University of North Carolina (UNC) at Chapel Hill. The effort was launched by **Frederick Brooks**, who was inspired by Sutherland's vision of the ultimate display as enabling a user to see, hear, and feel in the virtual world. Flight simulators had incorporated sound and haptic feedback for some time. Brooks selected molecular graphics as the principal driving problem of his program. The goal of Project GROPE, started by Brooks in 1967, was to develop a haptic interface for molecular forces. The idea was that, if the force constraints on particular molecular combinations could be "felt," then the designer of molecules could more quickly identify combinations of structures that could dock with one another.
>
> GROPE-I was a 2D system for continuous force fields. GROPE II was expanded to a full six-dimensional (6D) system with three forces and three torques. The computer available for GROPE II in 1976 could produce forces in real time only for very simple world models — a table top; seven child's blocks; and the tongs of the Argonne Remote Manipulator (ARM), a large mechanical device. For real-time evaluation of molecular forces, Brooks and his team estimated that 100 times more computing power would be necessary. After building and testing the GROPE II system, the ARM was mothballed and the project was put on hold for about a decade until 1986, when VAX computers became available. GROPE III, completed in 1988, was a full 6D system. Brooks and his students then went on to build a full-molecular-force-field evaluator and, with 12 experienced biochemists, tested it in GROPE IIIB experiments in 1990. In these experiments, the users changed the structure of a drug molecule to get the best fit to an active site by manipulating up to 12 twistable bonds.



The GROPE force feedback system

The test results on haptic visualization were extremely promising. The subjects saw the haptic display as a fast way to test many hypotheses in a short time and set up and guide batch computations. The greatest promise of the technique, however, was not in saving time but in improving situational awareness. Chemists using the method reported better comprehension of the force fields in the active site and of exactly why each particular candidate drug docked well or poorly. Based on this improved grasp of the problem, users could form new hypotheses and ideas for new candidate drugs.



The Docker haptic feedback system

The docking station is only one of the projects pursued by Brooks's group at the UNC Graphics Laboratory. The virtual world envisioned by Sutherland would enable scientists or engineers to become immersed in the world rather than simply view a mathematical abstraction through a window from outside. The UNC group has pursued this idea through the development of what Brooks calls "intelligence-amplifying systems." Virtual worlds are a subclass of intelligence-amplifying systems, which are expert systems that tie the mind in with the computer, rather than simply substitute a computer for a human.

In 1970, Brooks's laboratory was designated as an NIH Research Resource in Molecular Graphics, with the goal of developing virtual worlds of technology to help biochemists and molecular biologists visualize and understand their data and models. During the 1990s, UNC has collaborated with industry sponsors such as HP to develop new architectures incorporating 3D graphics and volume-rendering capabilities into desktop computers (HP later decided not to commercialize the technology).

Since 1985, NSF funding has enabled UNC to pursue the Pixel-Planes project, with the goal of constructing an image-generation system capable of rendering 1.8 million polygons per second and a head-mounted display system with a lagtime under 50 milliseconds. This project is connected with GROPE and a large software project for mathematical modeling of molecules, human anatomy, and architecture. It is also linked to VISTANET, in which UNC and several collaborators are testing high-speed network technology for joining a radiologist who is planning cancer therapy with a virtual world system in his clinic, a Cray supercomputer at the North Carolina Supercomputer Center, and the Pixel-Planes graphics engine in Brooks's laboratory.

With Pixel-Planes and the new generation of head-mounted displays, the UNC group has constructed a prototype system that enables the notions explored in GROPE to be transformed into a wearable virtual-

world workstation. For example, instead of viewing a drug molecule through a window on a large screen, the chemist wearing a head-mounted display sits at a computer workstation with the molecule suspended in front of him in space. The chemist can pick it up, examine it from all sides, even zoom into remote interior dimensions of the molecule. Instead of an ARM gripper, the chemist wears a force-feedback exoskeleton that enables the right hand to "feel" the spring forces of the molecule being warped and shaped by the left hand.

In a similar use of this technology, a surgeon can work on a simulation of a delicate procedure to be performed remotely. A variation on and modification of the approach taken in the GROPE project is being pursued by UNC medical researcher James Chung, who is designing virtual-world interfaces for radiology. One approach is data fusion, in which a physician wearing a head-mounted display in an examination room could, for example, view a fetus by ultrasound imaging superimposed and projected in 3D by a workstation. The physician would see these data fused with the body of the patient. In related experiments with MRI and CT scan data fusion, a surgeon has been able to plan localized radiation treatment of a tumor.

Movie 17.2 UNC Fetal Surgery VR

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/fetal-surgery-1.m4v

The term **Haptic** refers to our sense of touch, and consists of input via mechano-receptors in the skin, neurons which convey information about texture, and the sense of proprioception, which interprets information about the size, weight and shape of objects objects via feedback from muscles and tendons in the hands and other limbs. Haptic Feedback refers to the way we attempt to simulate this haptic sense in our virtual environment, by assigning physical properties to the virtual objects we encounter and designing devices to relay these properties back to the user. Haptic feedback devices use vibrators, air bladders, heat/cold materials, and Titanium-Nickel alloy transducers which provide a minimal sense of touch.

UNC uses a ceiling mounted ARM (Argonne remote manipulator) to test receptor sites for a drug molecule. The researcher, in virtual reality, grasps the drug molecule, and holds it up to potential receptor sites. Good receptor sites attract the drug, while poor ones repel it. Using a force feedback system, scientists can easily feel where the drug can and should go.
http://www.cs.unc.edu/Research/

In 1979, F.H. Raab and others described the technology behind what has been one of the most widely utilized tracking systems in the VR world — the Polhemus. This six degrees of freedom electromagnetic position tracking was based on the application of orthogonal electromagnetic fields. Two varieties of electromagnetic position trackers were implemented — one used alternating current (AC) to generate the magnetic field, and the other used direct current (DC).

In the Polhemus AC system, mutually perpendicular emitter coils sequentially generated AC magnetic fields that induced currents in the receiving sensor, which consisted of three passive mutually perpendicular coils. Sensor location and orientation therefore were computed from the nine induced currents by calculating the small changes in the sensed coordinates and then updating the previous measurements.



Polhemus 3space

In 1964 Bill Polhemus started Polhemus Associates, a 12-person engineering studies company working on projects related to navigation for the U.S. Department of Transportation and similar European and Canadian departments, in Ann Arbor, Michigan. His research was focused on determining an object's position and orientation in a three-dimensional space.

??He relocated the company to Malletts Bay in 1969 and the company went beyond studies and began focusing on hardware. In late 1970, after an influx of what Polhemus called "a very clever team from a division of Northrop Corp. (now Northrop Grumman Corp.) that had a lot of experience in development of miniaturized inertial and magnetic devices," the firm changed its name to Polhemus Navigation Sciences, later shortened to Polhemus, and incorporated in Vermont.



Polhemus tracking equipment

"The Polhemus system is used to track the orientation of the pilot's helmet," Polhemus said of the electromagnetic technology he pioneered. "The ultimate objective is to optically project an image on the visor of the pilot's helmet so he can look anywhere and have the display that he needs. … It's critical to know, in a situation like that, where the pilot's helmet is pointed, so you know what kind of a display to put up on the visor," he added before comparing the system to a "**heads-up display**" or "gun sight," which projects similar data onto an aircraft's windshield.

Polhemus was supported for a few years in the early 1970s by Air Force contracts. But by late 1973, "in the absence of any equity capital to speak of, we just ran dry," in his words. "By that time, however, the device looked attractive to a number of companies, and there were several bids for it. We finally wound up selling to the Austin Company," a large conglomerate with headquarters in Cleveland, Ohio.

The next few years saw the company change hands to McDonnell Douglas Corp. of St. Louis, Mo., and then to Kaiser Aerospace and Electronics Corp. of Foster City, Calif., in 1988.

Ernie Blood was an engineer and Jack Scully a salesman at Polhemus. Blood and Scully created the digitizer

used for George Lucas' groundbreaking Star Wars series, which won an Academy Award for Polhemus (Blood's name was on the patent.) They had been discussing possible expanded commercial uses for the Polhemus motion tracking technology, possibly in the entertainment field, in training situations, or in the medical field. However, Polhemus was focused on military applications, and was not interested in any other markets. When they took the idea of a spinoff company to their superiors at McDonnell-Douglas, the parent company of Polhemus, they were fired in 1986.

Still convinced that there were commercial possibilities, Blood and Scully started a new company in 1986, which they called Ascension. The first few years were lean years, but Blood improved upon the head-tracking technology for fighter pilots and Scully eventually negotiated a licensing agreement with GEC (General Electric Co. of Great Britain). The contract was put on hold for two years when Polhemus, which had been purchased by Kaiser Aerospace, a direct competitor of GEC, sued Ascension for patent infringement. Polhemus dropped the case shortly before it went to trial, and Ascension, with the financial backing of GEC, was able to stay afloat. The licensing agreement was finalized with GEC, and Ascension sales of equipment based on the technology took off, particularly in the medical field.

When the virtual reality revolution erupted in the early 1990s, Ascension played a part in it, developing motion trackers that could be used in high-priced games. "We decided from the beginning that we were not going to go after a single-segment application," Blood said. "From day one, we've always made sure we were involved in a lot of different markets." As the VR market declined, this philosophy helped Ascension's sales stay constant.

A constant for Ascension was its work in the field of animation. Scully says "Ascension deserves some of the credit for inventing real-time animation, in which sensors capture the motions of performers for the instant animation of computerized characters." Ascension's Flock of Birds product has been used to capture this motion and define the animated characters. It has been used in the animation of characters in hundreds of television shows (MTV's CyberCindy, Donkey Kong), commercials (the Pillsbury Doughboy, the Keebler elves), video games (Legend, College Hoops Basketball, SONY's The Getaway) and movies (Starship Warriors, and pre-animation for Star Wars).

Ascension Technology served six markets: animation, medical imaging, biomechanics, virtual reality, simulation/training and military targeting systems from its facility. Using DC magnetic, AC magnetic, infrared-optical, inertial and laser technologies, Ascension provides turnkey motion capture systems for animated entertainment as well as custom tracking solutions for original equipment manufacturers to integrate into their products.

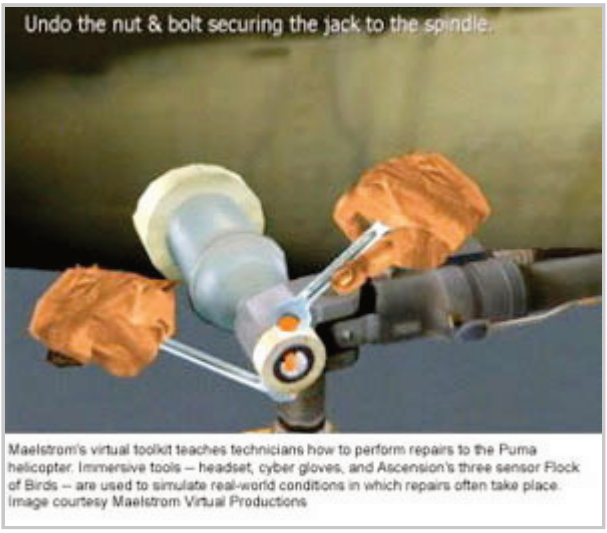
Sturman, D.J. and Zeltzer, D., *A survey of glove-based input*, Computer Graphics and Applications, IEEE, V14 #1, Jan. 1994,30 -39

F. Raab, E. Blood, T. Steiner, and H. Jones, Magnetic position and orientation tracking system, IEEE Transactions on Aerospace and Electronic Systems, Vol. 15, No. 5, 1979, pp. 709-718.



3D-BIRD mounted on Sony LDI-100 HMD. Audi TT Coupe virtual interior and exterior environment courtesy Eon Realty, Sweden.

3D Bird mounted on the back of a Sony LDI-100 HMD in Audi TT coupe



Maelstrom's virtual toolkit teaches technicians how to perform repairs to the Puma helicopter. Immersive tools – headset, cyber gloves, and Ascension's three sensor Flock of Birds – are used to simulate real-world conditions in which repairs often take place. Image courtesy Maelstrom Virtual Productions

Maelstrom's virtual toolkit teaches technicians how to perform repairs on the Puma helicopter, using Ascension Flock of Birds

17.5 Virtual Spaces



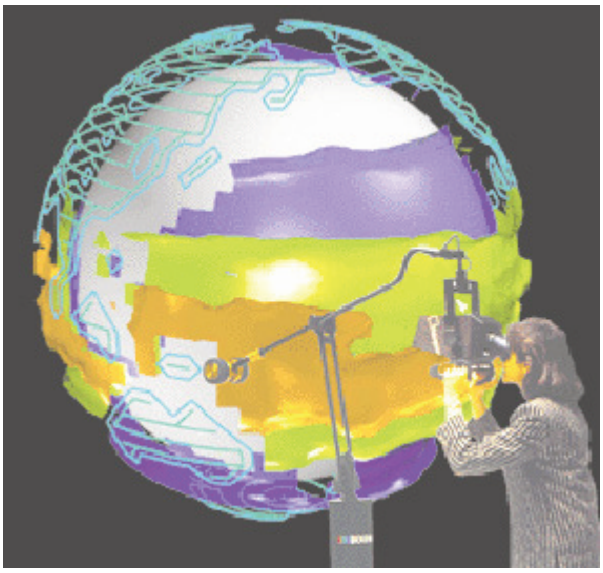
LEEP Optical System started to develop wide angle lenses for 3-D still photography applications in 1975. The Large Expanse, Extra Perspective (LEEP) optical system was designed by Eric Howlett in 1979 and provided the basis for most of the virtual reality helmets that were developed. The combined system gave a very wide field of view stereoscopic image. The users of the system were impressed by the sensation of depth in the scene and the corresponding realism.



Vived

The original LEEP system was redesigned for the NASA Ames Research Center in 1985 for their first virtual reality installation, the VIEW (Virtual Interactive Environment Workstation) by Scott Fisher. The system was built according to lessons learned using the LEEP display earlier, and proved to be quite impressive. It already featured many techniques that were often used: a Polhemus tracker, 3D audio output, gesture recognition using VPLs DataGlove, a remote camera, and a BOOM-mounted CRT display.

In 1988 Fakespace began building a telepresence camera system for the Virtual Environment Workstation (View) project at NASA Ames Research Center. The complete system combined a teleoperated camera platform and 3D viewing system.To increase image quality, Fakespace invented the BOOM (Binocular Omni-Orientation Monitor). Very small monitors were mounted on a mechanical arm, and users looked into the monitors like they would look into a pair of binoculars. Tracking occured when the user moved the arm, which changed the perspective. When a user released the BOOM, another person could look at the same thing from the same perspective, which was an advantage over HMDs. Since real monitors were used, the resolution was quite good.



BOOM system

The concept of a room with graphics projected from behind the walls was invented at the Electronic Visualization Lab at the University of Illinois Chicago Circle in 1992. The images on the walls were in stereo to give a depth cue. The main advantage over ordinary graphics systems was that the users were surrounded by the projected images, which means that the images were in the users' main field of vision.

This environment was called a "CAVE", (CAVE Automatic Virtual Environment). The first CAVE (as well as the concept) was created by Carolina Cruz-Neira, Dan Sandin, and Tom DeFanti, along with other students and staff of EVL. This back-projection method of virtual reality gained a strong following.

The CAVE was a surround-screen, surround-sound, projection-based virtual reality (VR) system. The illusion of immersion was created by projecting 3D computer graphics into a 10'x10'x10′ cube composed of display screens that completely surrounded the viewer. It was coupled with head and hand tracking systems to produce the correct stereo perspective and to isolate the position and orientation of a 3D input device. A sound system provided audio feedback. The viewer explored the virtual world by moving around inside the cube and grabbing objects with a three-button, wand-like device.

Unlike users of the video-arcade type of VR system, CAVE dwellers did not wear helmets to experience VR. Instead, they put on lightweight stereo glasses and walked around inside the CAVE as they interacted with virtual objects. Multiple viewers often shared virtual experiences and easily carried on discussions inside the CAVE, enabling researchers to exchange discoveries and ideas. One user was the active viewer, controlling the stereo projection reference point, while the rest of the users were passive viewers.

The CAVE was designed from the beginning to be a useful tool for scientific visualization; EVL's goal was to help scientists achieve discoveries faster, while matching the resolution, color and flicker-free qualities of high-end workstations. Most importantly, the CAVE could be coupled to remote data sources, supercomputers and scientific instruments via high-speed networks. It had obvious benefits: it was easy for several people to be in the room simultaneously and therefore see images together; and it was easy to mix real and virtual objects in the same

environment. Also, because users saw, for example, their own hands and feet as part of the virtual world, they got a heightened sense of being inside that world.

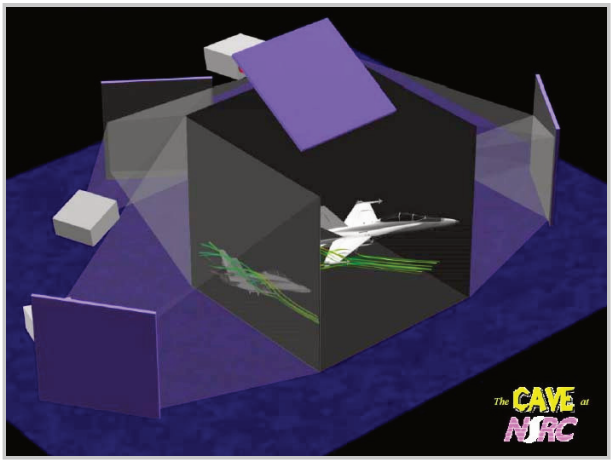
Various CAVE-like environments existed all over the world. Most of these had up to four projection surfaces; images were then usually projected on three walls and the floor. Adding projection on the ceiling gave a fuller sense of being enclosed in the virtual world. Projection on all six surfaces of a room allowed users to turn around and look in all directions. Thus, their perception and experience were never limited, which was necessary for full immersion. The PDC Cube at the Center for Parallel Computers at the Royal Institute of Technology in Stockholm in Sweden was the first fully immersive CAVE.

For a discussion of VR devices, see

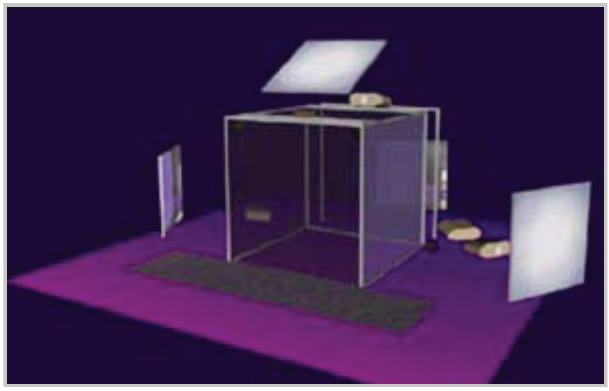
Review of Virtual Environment Interface Technology, IDA Paper P-3186, by Christine Youngblut, Rob E. Johnson, Sarah H. Nash, Ruth A. Wienclaw, and Craig A. Will

Virtual Reality in Training and Education: Resource Guide to Citations and Online Information

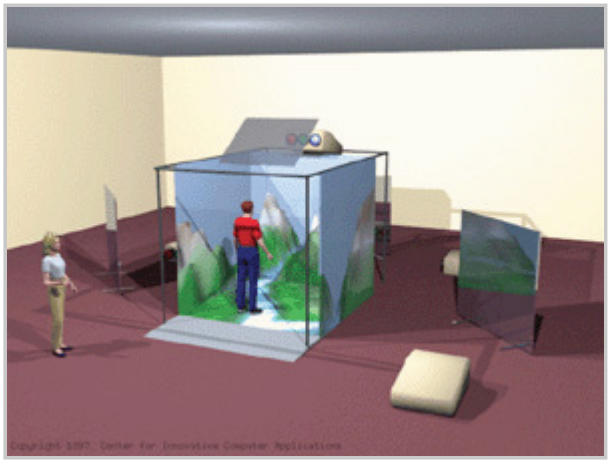
Gallery 17.1 CAVE Environments



A diagram of the CAVE at the National Supercomputing Research Center (NSRC). The CAVE (CAVE Automatic Virtual Environment) was developed by DeFanti, et al at the University of Illinois. This CAVE installation is an enclosed 10 feet cube room-sized advanced visualization tool that combines high-resolution, stereoscopic projection and 3D computer graphics to create the illusion of complete immersion in a virtual environment.



CAVE environment



CAVE installed at IU

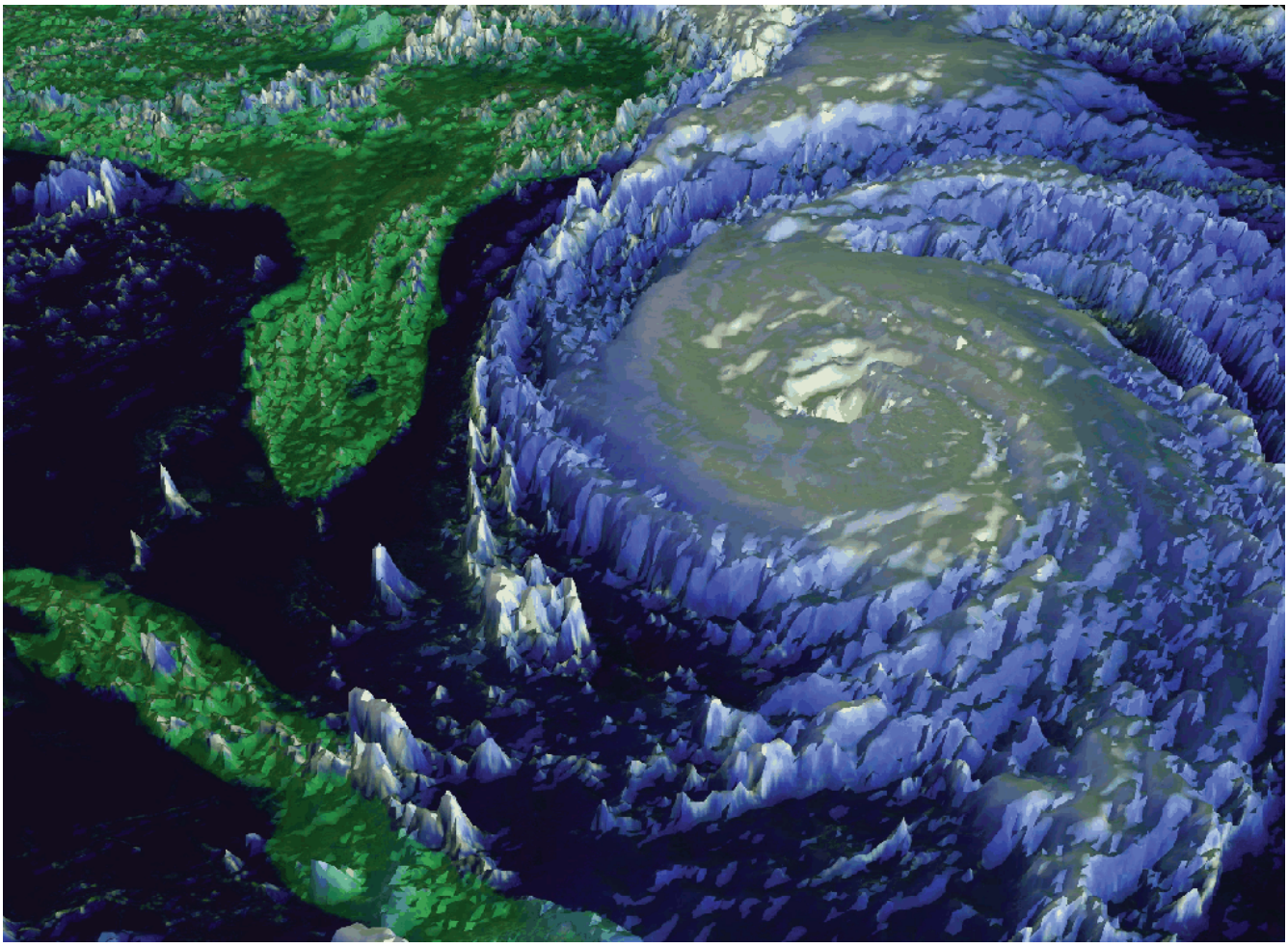


Crayoland

Chapter 18: Scientific Visualization

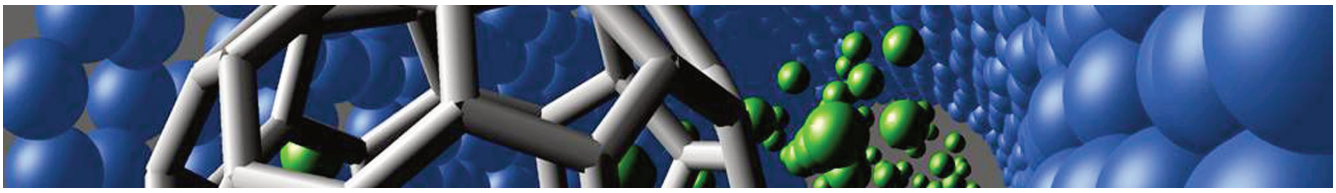
Scientific Visualization

3D graphics techniques provided a means of creating a visual representation of complex and extensive data collections. In particular, scientific data sets were quite large, and the growth area around this visual image creation was called *scientific visualization.*

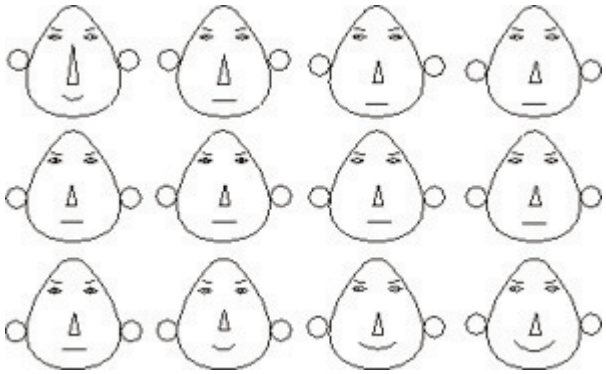


Hurricane Fran – NASA (1996)

18.1 Introduction



Visualization in its broadest terms represents any technique for creating images to represent abstract data. Thus much of what we do in computer graphics and animation can fall into this category. One specific area of visualization, though, has evolved into a discipline of its own. We call this area Scientific Visualization, or Visualization in Scientific Computing, although the field encompasses other areas, for example business (information visualization) or computing (process visualization).



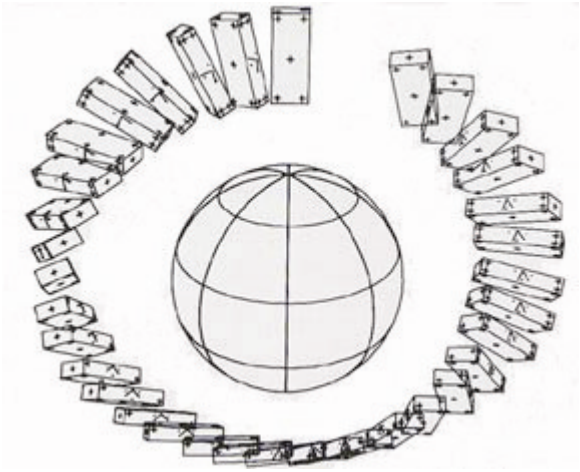
Chernoff faces

In 1973, Herman Chernoff introduced a visualization technique to illustrate trends in multidimensional data. His Chernoff Faces were especially effective because they related the data to facial features, something which we are used to differentiating between. Different data dimensions were mapped to different facial features, for example the face width, the level of the ears, the radius of the ears, the length or curvature of the mouth, the length of the nose, etc. An example of Chernoff faces is shown to the left; they use facial features to represent trends in the values of the data, not the specific values themselves. While this is clearly a limitation, knowledge of the trends in the data could help to determine which sections of the data were of particular interest.

In general the term "**scientific visualization**" is used to refer to any technique involving the transformation of data into visual information, using a well understood, reproducible process. It characterizes the technology of using computer graphics techniques to explore results from numerical analysis and extract meaning from complex, mostly multi-dimensional data sets. Traditionally, the visualization process consists of filtering raw data to select a desired resolution and region of interest, mapping that result into a graphical form, and producing an image, animation, or other visual product. The result is evaluated, the visualization parameters modified, and the process

run again. The techniques which can be applied and the ability to represent a physical system and the properties of this system are part of the realm of scientific visualization.

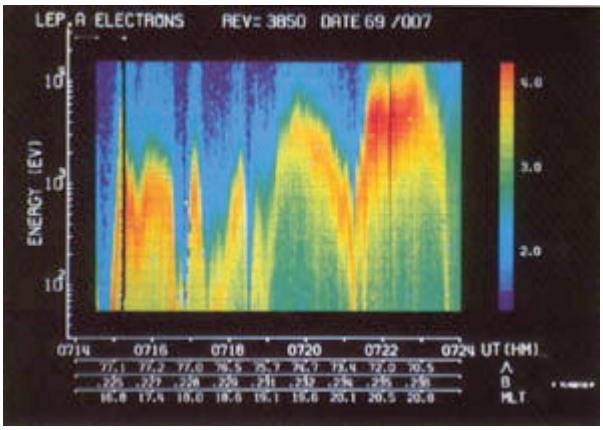
Visualization is an important tool often used by researchers to understand the features and trends represented in the large datasets produced by simulations on high performance computers.



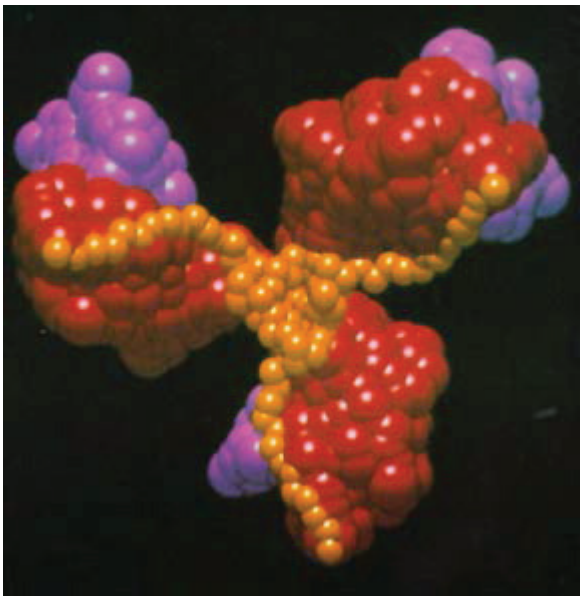
Zajac film composite

From the early days of computer graphics, users saw the potential of this image to present technology as a way to investigate and explain physical phenomena and processes, many from space physics or astrophysics. Ed Zajac from Bell Labs produced probably one of the first visualizations with his animation titled *A two gyro gravity gradient altitude control system*. Nelson Max at Lawrence Livermore used the technology for molecular visualization, making a series of films of molecular structures. Bar graphs and other statistical representations of data were commonly generated as graphical images. Ohio State researchers created a milestone visualization film on the interaction of neighboring galaxies in 1977.

One of the earliest color visualizations was produced in 1969 by Dr. Louis Frank from the University of Iowa. He plotted the energy spectra of spacecraft plasma by plotting the energy against time, with color representing the number of particles per second measured at a specific point in time.



Louis Frank visualization



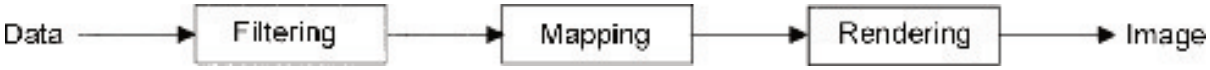
Nelson Max molecular visualization

One of the most well-known examples of an early process visualization is the film “Sorting out Sorting”, created by Ronald Baecker at the University of Toronto in 1980, and presented at SIGGRAPH 81. It explained concepts involved in sorting an array of numbers, illustrating comparisons and swaps in various algorithms. The film ends with a race among nine algorithms, all sorting the same large random array of numbers.The film was very successful, and is still used to teach the concepts behind

sorting. Its main contribution was to show that algorithm animation, by using computer generated images, can have great explanatory power.

Three-dimensional imaging of medical datasets was introduced shortly after clinical CT (Computed axial tomography) scanning became a reality in the 1970s. The CT scan process images the internals of an object by obtaining a series of two-dimensional x-ray axial images. The individual x-ray axial slice images are taken using a x-ray tube that rotates around the object, taking many scans as the object is gradually passed through a gantry. The multiple scans from each 360 degree sweep are then processed to produce a single cross-section.

The goal in the visualization process is to generate visually understandable images from abstract data. Several steps must be done during the generation process. These steps are arranged in the so called Visualization Pipeline.



Data is obtained either by sampling or measuring, or by executing a computational model. Filtering is a step which pre-processes the raw data and extracts information which is to be used in the mapping step. Filtering includes operations like interpolating missing data, or reducing the amount of data. It can also involve smoothing the data and removing errors from the data set. Mapping is the main core of the visualization process. It uses the pre-processed filtered data to transform it into 2D or 3D geometric primitives with appropriate attributes like color or opacity. The mapping process is very important for the later visual representation of the data. Rendering generates the image by using the geometric primitives from the mapping process to generate the output image. There are number of different filtering, mapping and rendering methods used in the visualization process.

Gabor Herman was a professor of computer science at SUNY Buffalo in the early 1970s, and produced some of the earliest medical visualizations, creating 3D representations from the 2D CT scans, and also from electron microscopy. Early images were polygons and lines (e.g., wireframe) representing three-dimensional volumetric objects. James Greenleaf of the Mayo Clinic and his colleagues were the first to introduce methods to extract information from volume data, a process called **volume visualization**, in 1970 in a paper that demonstrated pulmonary blood flow.

Mike Vannier and his associates at the Mallinckrodt Institute of Radiology, also used 3D imaging as a way of abstracting information from a series of transaxial CT scan slices. Not surprisingly, many early applications involved the visualization of bone, especially in areas like the skull and craniofacial regions (regions of high CT attenuation and anatomic zones less affected by patient motion or breathing). According to Elliot Fishman from Johns Hopkins, although most radiologists at the time were not enthusiastic about 3D reconstructions, referring physicians found them extremely helpful in patient management decisions, especially in complex orthopedic cases.In 1983, Vannier adapted his craniofacial imaging techniques to uncover hidden details of some of the world’s most important fossils.

There are other early examples that used graphics to represent **isolines** and **isosurfaces**, cartographic information, and even some early **computational fluid dynamics**. But the area that we now call scientific visualization really didn’t come into its own until the late 1980s.

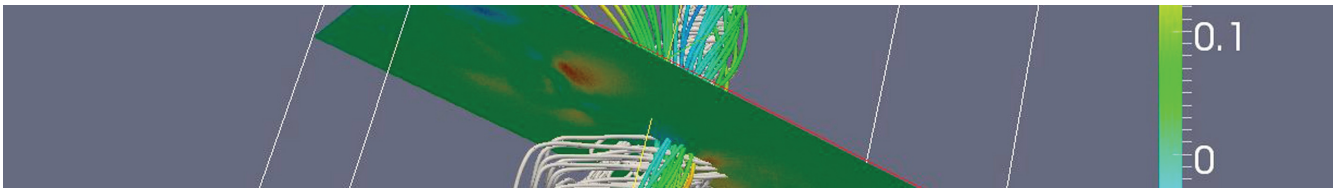
Herman Chernoff, The use of faces to represent points in k-dimensional space graphically, Journal of the American Statistical Association, V68, 1973.

To see a Java based demonstration of sorting algorithms, similar to the visualization done by Baecker, go to
http://www.cs.ubc.ca/spider/harrison/Java/sorting-demo.html

Herman, G.T., Liu, H.K.: Three-dimensional display of human organs from computed tomograms, Computer Graphics and Image Processing 9:1-21, 1979

Michael W. Vannier , Jeffrey L. Marsh , James O. Warren, Three dimensional computer graphics for craniofacial surgical planning and evaluation, Proceedings of SIGGRAPH 83, Detroit, Michigan

18.2 Visualization Systems



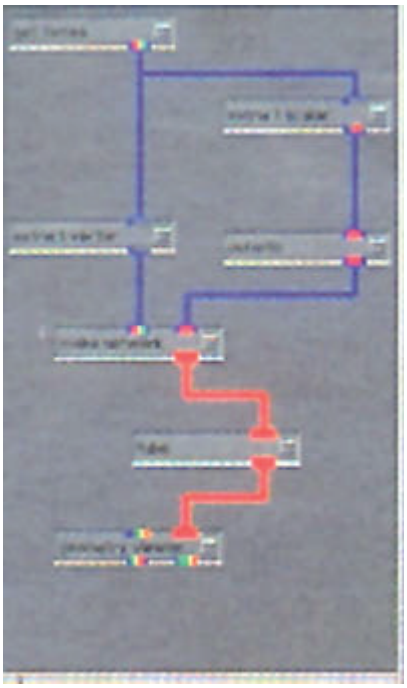


Special Issue on Visualization in Scientific Computing, Computer Graphics, Publication of ACM/SIGGRAPH, Vol 21, No. 6, November 1987.Bruce McCormick, Maxine Brown, and Tom DeFanti

In 1987 an ACM-SIGGRAPH panel released a report done for the National Science Foundation, *Visualization in Scientific Computing*, that was a milestone in the development of the emerging field of Scientific Visualization. As a result, the field was now on the radar screen of funding agencies, and conferences, workshops and publication vehicles soon followed.

Publication of this NSF report prompted researchers to investigate new approaches to the visualization process and also spawned the development of integrated software environments for visualization. Besides several systems that only addressed specific application needs, such as computational fluid dynamics or chemical engineering, a few more general systems evolved. Among these were IBM's Data Explorer, Ohio State University's apE, Wavefront's Advanced Visualizer, SGI's IRIS Explorer, Stardent's AVS and Wavefront's Data Visualizer.Two lesser known but important systems were Khoros (from the University of New Mexico) and PV-WAVE (Precision Visuals' Workstation Analysis and Visualization Environment), originally from Precision Visuals, Inc., but later owned by Visual Numerics, Inc. (VNI).

These visualization systems were designed to take the burden of making the visualization image off of the shoulders of the scientist, who often didn't know anything of the graphics process. The most usable systems therefore utilized a visual programming style interface, and were built on the *dataflow* paradigm: software modules were developed independently, with standardized inputs and outputs, and were visually linked together in a pipeline. They were sometimes referred to as **modular visualization environments** (MVEs). MVEs allowed the user to create visualizations by selecting program modules from a library and specifying the flow of data between modules using an interactive graphical networking or mapping environment. In a MVE **dataflow** diagram, the boxes represent process modules, which are linked by lines representing the flow of data between the modules. Maps or networks could be saved for later recall.



Dataflow diagram

General classes of modules included:

- data readers – input the data from the data source
- data filters – convert the data from a simulation or other source into another form which is more informative or less voluminous.
- data mappers – convert it into another completely different domain, such as 2D or 3D geometry or sound.
- viewers or renderers- rendering the 2D and 3D data as images.
- control structures – examples include initialization of the display device, control of recording devices, open graphics windows, etc.
- data writers – output the original or filtered data

Advantages of MVEs included:

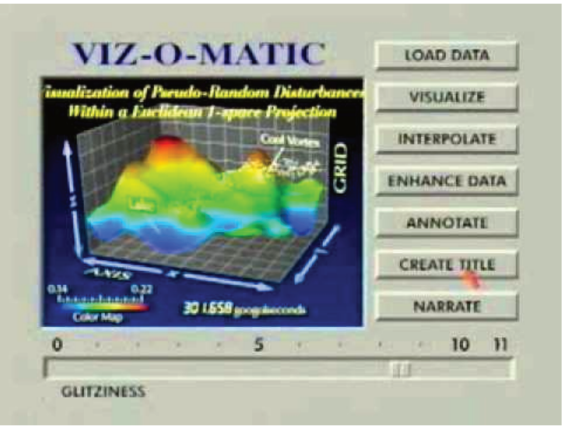
- Required no graphics expertise
- Allowed for rapid prototyping and interactive modifications
- Promoted code reuse
- Extensible- allowed new modules to be created
- Reasonably powerful and complete for a broad range of problems
- Often allowed computations to be distributed across machines, networks and platforms

The problem with such packages included poor performance on large data sets, they were more restrictive than general programming environments, they were often not built on accepted graphics standards, and their ease of use sometimes promoted poor visualizations (this often involved a "high glitz factor").

Wayne Lytle, who worked with the Cornell Theory Center, produced this parody of scientific visualizations for SIGGRAPH 93, called *The Dangers of Glitziness and Other Visualization Faux Pas*, using fictitious software named "Viz-o-Matic." The video documents the enhancement and subsequent "glitz buffer overload of a sparsely

data-driven visualization trying to masquerade as a data-driven, thoughtfully rendered presentation," according to Lytle.

Movie 18.1 Viz-O-Matic

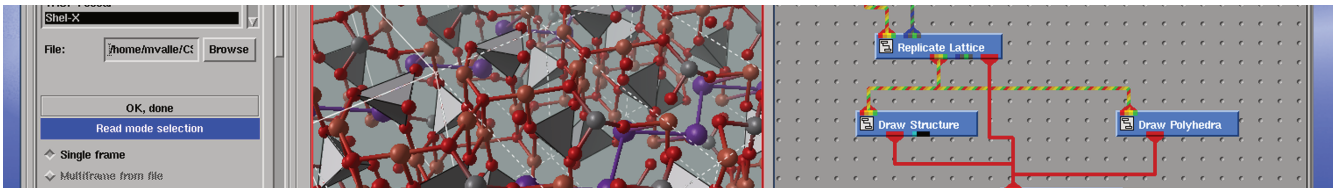


https://www.youtube.com/watch?v=fP-7rhb-qMg

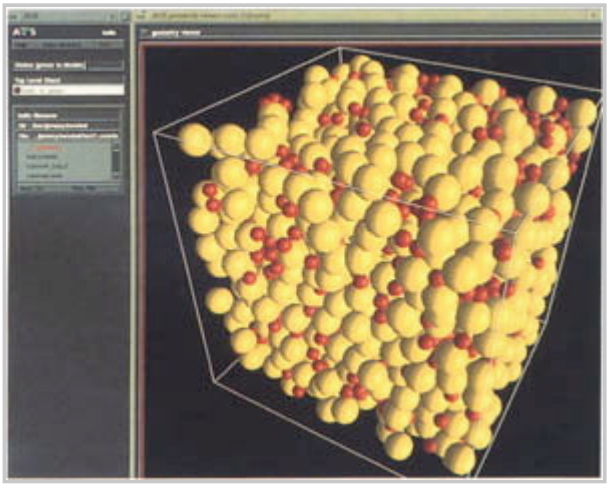
Viz-o-Matic – The Dangers of Glitziness and Other Visualization Faux Pas, or What's Wrong With This Visualization?

by Wayne Lytle – Cornell University Theory Center, 1993.

18.3 Hardware and Software



In the mid 80's, Stellar Computer was marketing a graphic supercomputer. To demonstrate the capabilities of their hardware, they developed a software package called Application Visualization System (AVS) that they gave away with the hardware. AVS was one of the first integrated visualization systems, and was developed by Digital Productions veteran Craig Upson and others. Over time, Stellar merged with Ardent Computer to become Stardent Computer. When business conditions changed, some of the engineering staff and management of Stardent formed a new company called Advanced Visual Systems, Inc. to continue the development of the AVS product line.



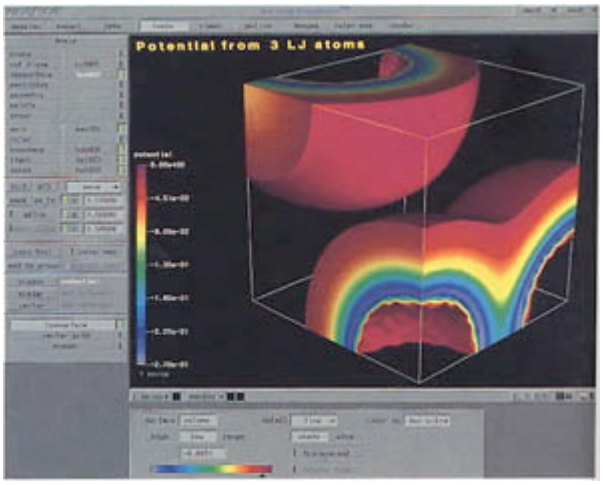


Screenshots from AVS

The computational model of AVS was based on a collection of parametric modules, that is, autonomous building blocks which could be connected to form larger data processing networks. Each module had definite I/0 dataflow properties, specified in terms of a small collection of data structures such as field, **colormap**, or geometry. The Network Editor, operating as a part of the AVS kernel, offered interactive visual tools for selecting modules, specifying connectivity and designing convenient GUIs to control module parameters. A set of base modules for mapping, filtering, and rendering was built into the AVS kernel. The user extensibility model was defined at the C/Fortran level, allowing for new

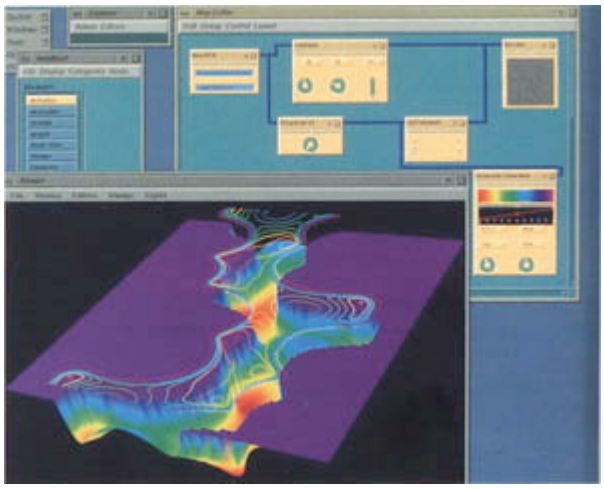
modules to be constructed and appended to the system in the form of independent UNIX processes, supported by appropriate dataflow interfaces.

> Dana Computer Inc. was founded by Allen Michels in Sunnyvale, California in the early 1980s. The company was renamed Ardent Computer in December 1987 because another company named Dana Computer already existed. Ardent was financed by venture capital and Kubota Ltd., (Kubota paid $50,000,000 for 44% of Ardent). In 1989 Ardent merged with Newton, Mass. based Stellar Computer to become Stardent Computer. The Sunnyvale facility was closed in 1990, followed soon after by the Massachusetts facility. Kubota Pacific Computer then gained the intellectual property from Stardent. Kubota Pacific Computer became Kubota Graphics Corporation and lasted until February 1, 1995. Several industry notables worked for Ardent including Gordon Bell, the founder of DEC, who was VP of Engineering.



Screenshot from Advanced Visualizer

Other visualization systems came out of the commercial animation software industry. The Wavefront Advanced Visualizer was a modeling, animation and rendering package which provided an environment for interactive construction of models, camera motion, rendering and animation without any programming. The user could use many supplied modeling primitives and model deformations, create surface properties, adjust lighting, create and preview model and camera motions, do high quality rendering, and save the resulting images for writing to video tape. It was more of a general graphics animation system, but was used for many scientific visualization projects.



Screenshot from Iris Explorer

Iris Explorer was a data-flow, object-oriented system for data visualization developed by G. J. Edwards and his colleagues at SGI. The product was later marketed by NAG (Numerical Applications Group). Like other dataflow

systems, it allowed the user to connect pre-built modules together using a “drag and drop” approach. The modules were X Windows programs developed in C or FORTRAN, and was built around the OpenGL standard.

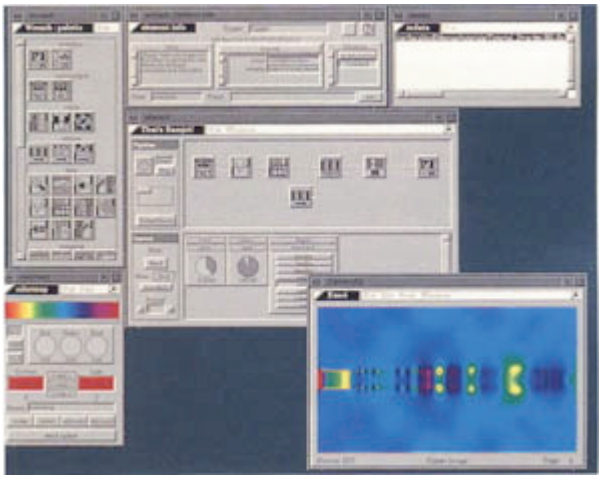
Iris Explorer had three main components:

- The Librarian module contained the list of modules and previously created maps
- The Map Editor was the work area for creating and modifying maps.
- DataScribe was a data conversion tool for moving data between Explorer and other data formats

A map was a dataflow network of modules connected or “wired” together. The user wired together the modules by connecting the appropriate ports, e.g. the output port of one module to the input port of the next module. Each module accepted data, processed it, and then output it to the next module. A map could be created and then stored for future use. It could also be made part of another map.

Explorer Data Types

- Parameter (scalar)
- Lattice (array, including images)
- Pyramid (irregular grid)
- Geometry (Inventor-based)
- Pick (user interaction with geometry)
- In addition, users could define their own types with a typing language

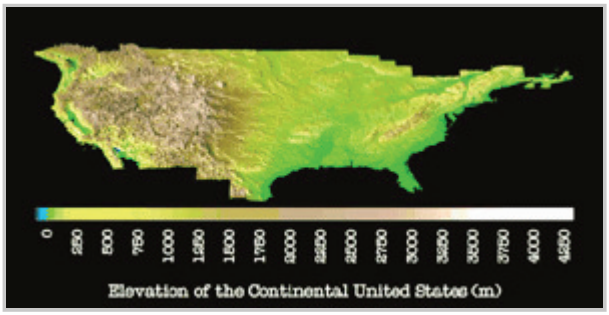


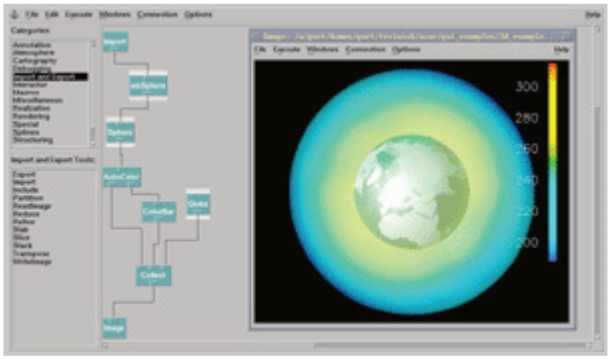
Screenshot from apE

In 1984, Ohio State University competed for an NSF supercomputer center, but was unsuccessful. So the University took the proposal to the state legislature, who established the Ohio Supercomputer as a state center in 1987. One of the reasons for the success of the proposal was the connection with Ohio State’s very highly regarded Computer Graphics Research Group, which became the Advanced Computing Center for the Arts and Design at about the same time. The connection was made formal when the Ohio Supercomputer Graphics Project of ACCAD was made part of the OSC structure. Researchers from OSGP set out to develop a visualization package based on the dataflow paradigm, and in 1988 the apE (animation production Environment) software was released. It was originally distributed free of charge to any users who wanted to use it, and it allowed for these users to write their own modules to extend the capabilities.

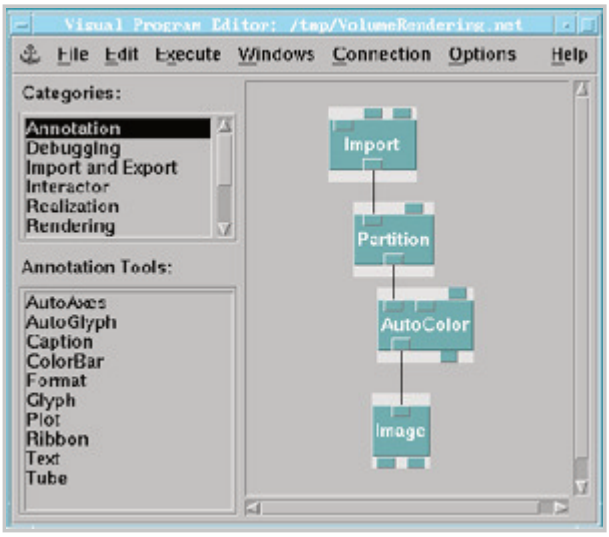
In 1991 OSC decided to commercialize this popular free software, and contracted with Taravisuals, Inc. to maintain and distribute it. Unfortunately, at about the same time, Iris Explorer was released and was freely bundled with the SGI workstation, one of the more popular apE platforms, and the apE effort was discontinued.

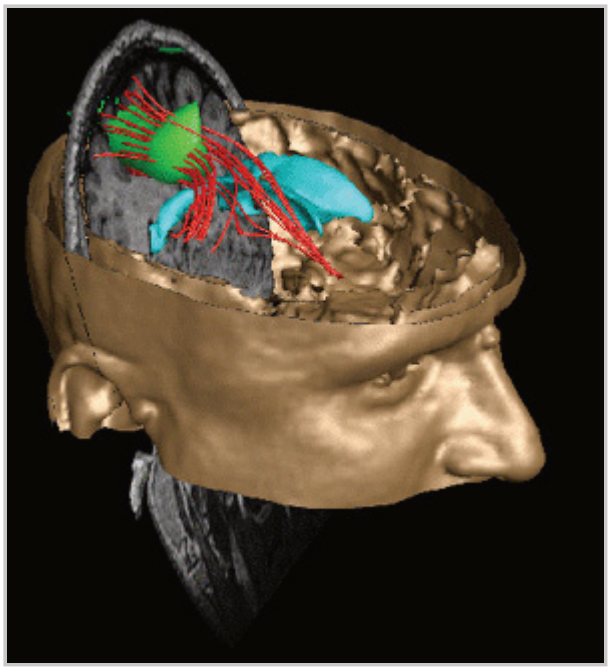
Like most of the other systems of the time, Data Explorer (DX) was a general-purpose visualization application in which the user created visualizations by combining existing modules into a network. It was discipline independent and easily adaptable to new applications and data. The program provided a full set of tools for manipulating, transforming, processing, realizing, rendering and animating data.





Screenshots from Data Explorer





Registered 3D MRI and Magnetoencephalographic ?Scans – NYU Medical Center

DX used visual programming and a data flow approach to visualization and analysis. The data flow modules were connected together to direct the data flow. This was analogous to creating a flow chart, and the resulting diagrams were called networks.

Users could work solely with the modules that came with Data Explorer or they could create macros. A macro was a network that was named and used in place of a module. There grew a large public collection of these macros that users could download.

DX provided visualization and analysis methods based on points, lines, areas, volumes, images or geometric primitives in any combination. It worked with 1-, 2-, and 3-dimensional data and with data which was rectangularly gridded, irregularly gridded, gridded on a non-rectangular grid, or scattered.

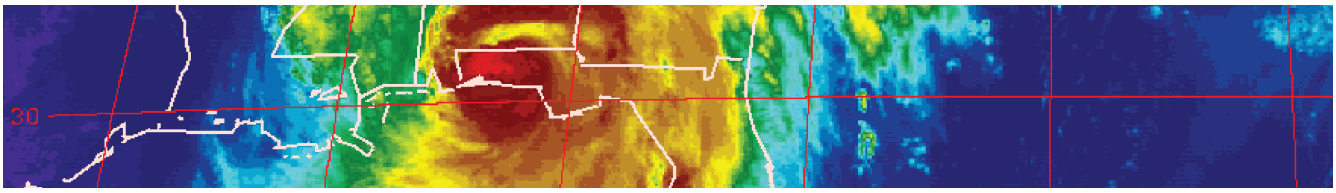
B. Lucas et al. *An architecture for a scientific visualization system*. In Proceedings of Visualization ’92, pages 107–114. IEEE Computer Society Press, 1992

Craig Upson, et al, *The Application Visualization System: A Computational Environment for Scientific Visualization*, IEEE CG&A, July 1989, pp 30-42

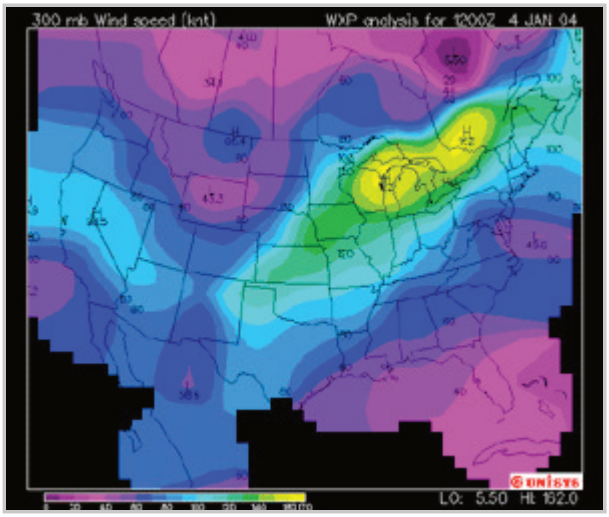
G.J. Edwards. The design of a second generation visualization environment. In J.J. Connor, S. Hernandez, T.K.S. Murthy, and H. Power, editors, Visualization and Intelligent Design in Engineering and Architecture, pages 3-16.

D. Scott Dyer. *A dataflow toolkit for visualization*. IEEE Computer Graphics and Applications, 10(4):60–69, July 1990

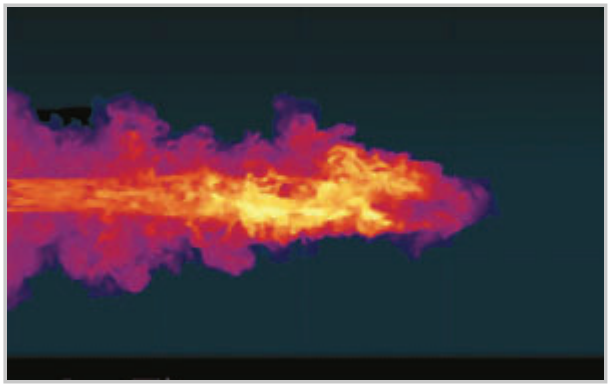
18.4 Algorithms



Most of the early visualization techniques dealt with 2D scalar or vector data that could be expressed as images, wireframe plots, scatter plots, bar graphs or contour plots. Contour plots are basically images of **multivariate data** that represent the thresholds of data values, that is for example fi(x,y)<=ci. The contours ci are drawn as curves in 2D space, and the shading represents values that are less than the contour value, and greater than the lower one. Often, the contour plots are redrawn over time, to get an animated sequence of a phenomenon. For example, Mike Norman of NCSA created an animation of a gas jet using sequential shaded **contour plots**.

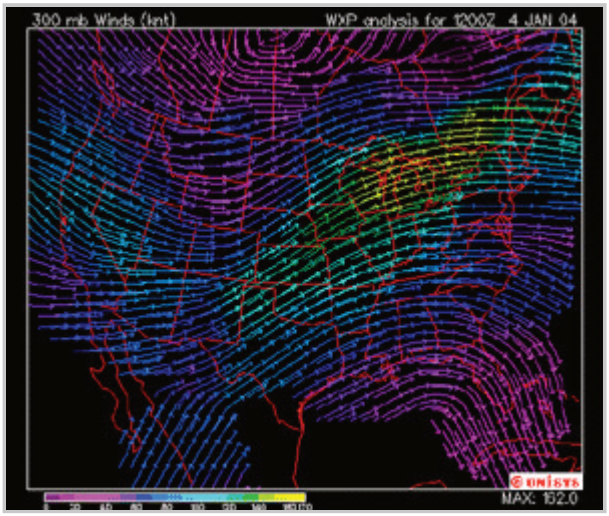


Contour Plot

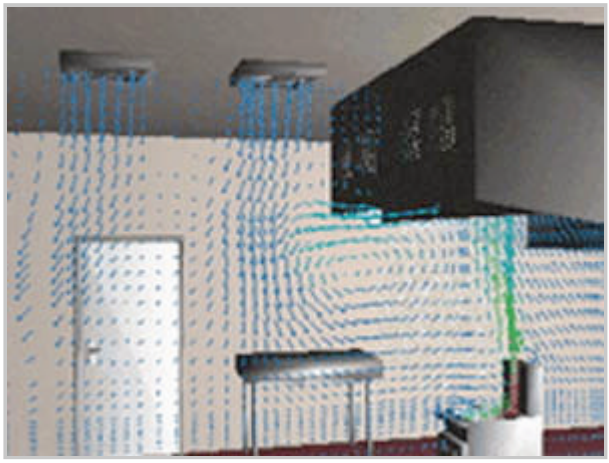


Contour Plot – Norman

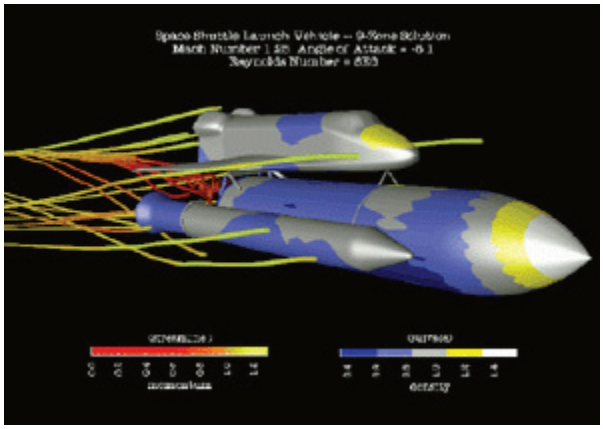
Vector or flow fields provide an effective means of visualizing certain phenomena, such as wind, gases, smoke, etc. By giving a direction to data within a certain interval, one could easily determine patterns within the data. For example, a stream plot was an example of a vector field which can be used to depict wind over the United States, as in the image to the above right. The image below the stream plot shows cool air entering a kitchen through ceiling vents, and the vectors show how the direction and temperature of the air changes as it is influenced by a gas-fired appliance, like a stove.



Vector Field – Wind flow over the U.S.



Vector Field – Air flow in commercial kitchen.



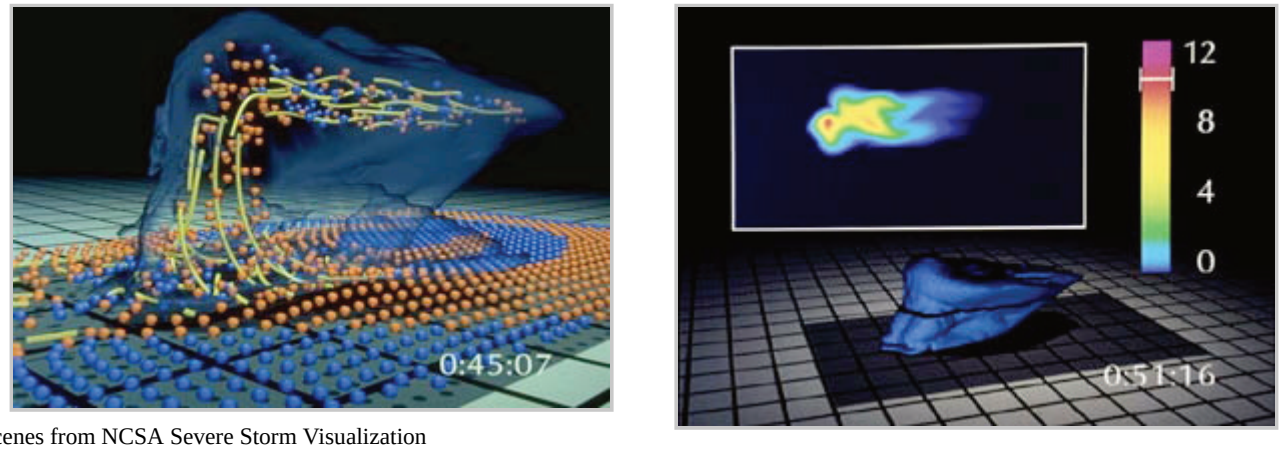
Momentum is shown as streamlines colored by magnitude and the density on the shuttle surface is shown as shaded contours – NASA Ames

Any of these techniques can be combined, as is shown in the visualization of the energy over the space shuttle In this case, stream lines represent one data domain, while shaded contours represent another domain.

3D visualization presented a more difficult problem. Data that is obtained in 3D usually needs to be converted to an alternative geometric form in order to send it to the rendering part of the pipeline. Early researchers, like Herman (mentioned in Section 1) and Harris in the late 1970s used primitive techniques to map the "values" of CT scans into 3D volumes, but the computational overhead was tremendous. One approach, which utilized the "**lofting**" algorithm developed by Henry Fuchs, et al, involved tracing the important boundaries from the planar scans, and then joining the adjacent traces with triangles to create a 3D surface.

Probably the most important 3D geometry conversion algorithm was presented by Bill Lorensen an Harvey Cline of General Electric in 1987. The Marching Cubes algorithm defined cubes between two adjacent planar data scans. Then it used a particular density value, or contour value, and "marched" from cube to cube, finding the portions of the cube that had the same contour value, subdividing the cube as necessary in the process. When all surfaces of all cubes having the same value were presented, a "level" surface or isosurface was created, which could then be rendered.

One of the most famous examples of isosurfaces in visualization was done by Wilhelmson and others at NCSA at the University of Illinois in 1990. It was an animated visualization of a severe storm, and besides the surfaces, it used other techniques, like contour shading, flowlines, stream lines and ribbons, etc. to tell the scientific story of the storm. The isosurfaces were supplemented with flow lines and stream lines to depict the details of the storm.

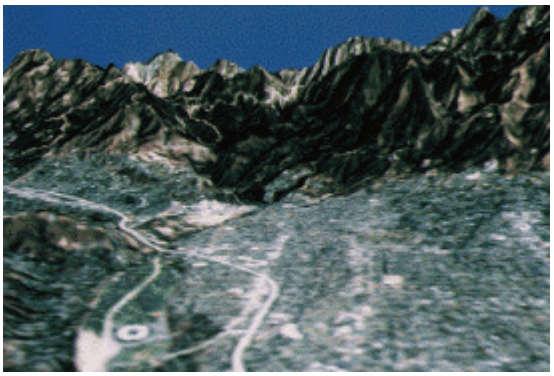


Scenes from NCSA Severe Storm Visualization

As mentioned above, data acquisition can be accomplished in various ways (CT scan, MRI scans, ultrasound, confocal microscopy, computational fluid dynamics, etc.). Another acquisition approach is remote sensing. Remote sensing involves gathering data and information about the physical "world" by detecting and measuring phenomena such as radiation, particles, and fields associated with objects located beyond the immediate vicinity of a sensing device(s).

It is most often used to acquire and interpret geospatial data for features, objects, and classes on the Earth's land surface, oceans, and atmosphere, but can also be used to map the exteriors of other bodies in the solar system, and other celestial bodies such as stars and galaxies.

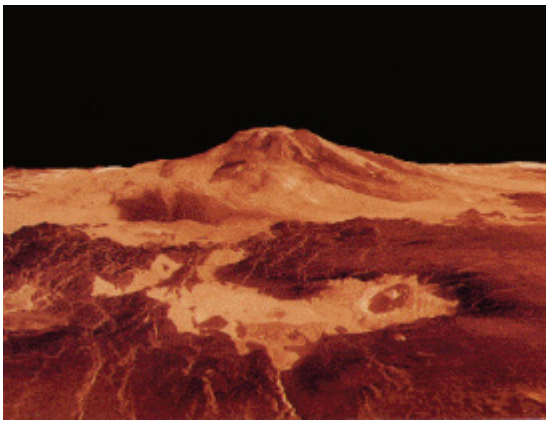
Data is obtained via aerial photography, spectroscopy, radar, radiometry and other sensor technologies. The filtering and mapping steps of the visualization pipeline vary, depending on the type of data acquisition method. One of the most famous **remote sensing** related visualizations is seen in the animation *L.A. the Movie*, produced by the Visualization and Earth Sciences Application group at JPL. The VESA group has performed data visualization at JPL since the mid 1980's.



Scene from L.A. the Movie. The Rose Bowl is in the foreground and JPL is in the foothills of the San Gabriel Mountains.

L.A. The Movie is a 3D perspective rendering of a flight around the Los Angeles area starting off the coast behind Catalina Island and includes a brief flight up the San Andreas Fault-line.

Since then the group produced other animations including flights around Mars, Venus, Miranda (a moon of Jupiter) and more. *L.A. the Movie* was created in 1987 utilizing multispectral image data acquired by the Landsat earth orbiting spacecraft. The remotely sensed imagery was rendered into perspective projections using digital elevation data sets available for the area within a Landsat image.



Scene from Mars the Movie

For more information about remote sensing, go to https://landsat.gsfc.nasa.gov/education/formal-education/

To read more about the L.A. the Movie process see *Animation and Visualization of Space Mission Data* in the August 1997 issue of Animation World Magazine

Harris, Lowell D., R. A. Robb, T. S. Yuen, AND E. L. Ritman, "Non-invasive numerical dissection and display of anatomic structure using computerized x-ray tomography," Proceedings SPIE 152 pp. 10-18 (1978).

H. Fuchs , Z. M. Kedem , S. P. Uselton, *Optimal surface reconstruction from planar contours*, Communications of the ACM, v.20 n.10, p.693-702, Oct. 1977

William E. Lorensen , Harvey E. Cline, *Marching cubes: A high resolution 3D surface construction algorithm*, ACM SIGGRAPH Computer Graphics, v.21 n.4, p.163-169, July 1987

The Visualization Toolkit — An Object-Oriented Approach to 3D Graphics, by Will Schroeder, Ken Martin and Bill Lorensen, Prentice Hall, 1996

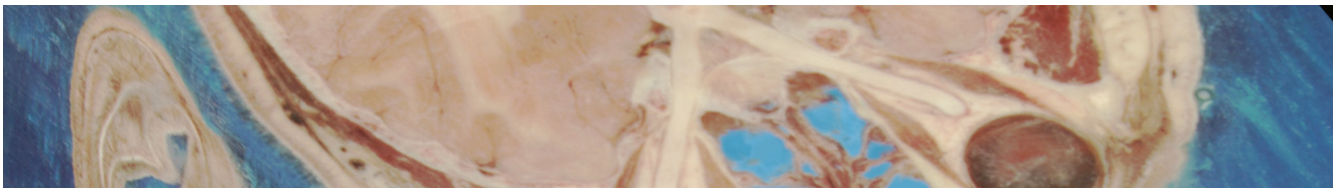
David M. Reed, Lawson Wade, Peter G. Carswell, and Wayne E. Carlson. "Particle Tracing in Curvilinear Grids," Proceedings of the IS&T/SPIE Symposium on Electronic Imaging: Science and Technology, Visual Data Exploration and Analysis II, The International Society for Optical Engineering, IS&T/SPIE Proc. 2410, February, 1995, pp 120-128.

Movie 18.2 *L.A. The Movie (1987) – 3D terrain animation created at JPL, circa 1987.*
http://www.youtube.com/watch?v=6RsXCbpJG54

Movie 18.3 *Mars The Movie (1989) – 3D terrain animation created at JPL, circa 1989 – a follow-up to their prior film LA: The Movie*
http://www.youtube.com/watch?v=vMjlD6h2qko

Movie 18.4 *NCSA Severe Storm Visualization (Visualization Of An F3 Tornado Within A Supercell Thunderstorm Simulation) – Scientists used pre-storm conditions from an observed F4 tornado in South Dakota in 2003 to initialize a simulation that produces a severe supercell storm that produces a powerful tornado and terabytes of data, which is used to drive the visualization.*
http://www.youtube.com/watch?v=EgumU0Ns1YI

18.5 Volumes



Another major approach to 3D visualization was **Volume Rendering**. Volume rendering allows for the display of information throughout a 3D data set, not just on the surface. There are several famous methods of volume rendering that should be discussed. The first was developed at Pixar for the Pixar Image Computer in 1988 by Robert Drebin and others. The algorithm used independent 3D cells within the volume, called "**voxels**". The basic assumption was that the volume was composed of voxels that each had the same property, such as density. A surface would occur between groups of voxels with two different values. The algorithm used color and intensity values from the original scans and gradients obtained from the density values to compute the 3D solid.



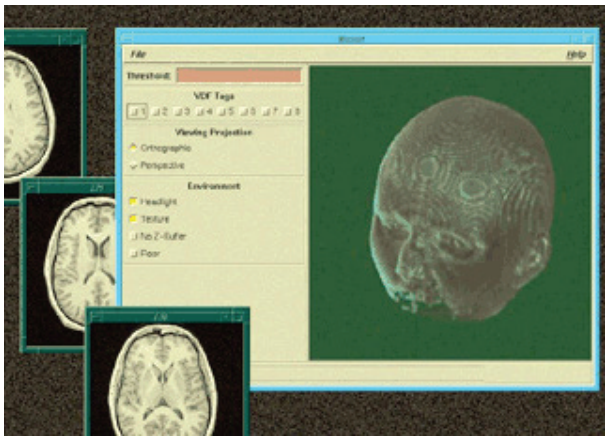
3D Voxel based volume rendering (Drebin)



Fig. 8. Volume rendering of head.

3D ray-traced volume rendering (Levoy)

The second approach used ray-tracing. The basic idea was to cast rays from screen pixel positions through the data, obtain the desired information along the ray, and then display this information. The data could be an average of the data in a cell, called a "voxel", or of all cells intersected by the ray, or some other such measure. This was used in areas such as medical imaging and displaying seismic data. The first major contribution was by Marc Levoy of the University of North Carolina in 1988. There have subsequently been many variations on the ray-tracing volume rendering approach.



Splatting approach to volume rendering

A third approach was developed by Lee Westover of UNC. *Splatting* is a volume rendering algorithm that combines efficient volume projection with a sparse data representation. In **splatting**, the final image is generated by computing for each voxel in the volume dataset its contribution to the final image. Only voxels that have values inside a determined iso-range need to be considered, and these voxels can be projected via efficient rasterization schemes. In splatting, each projected voxel is represented as a radially symmetric interpolation kernel, equivalent to a fuzzy ball. Projecting such a basis function leaves a fuzzy impression, called a footprint or splat, on the screen. The algorithm works by virtually "throwing" the voxels onto the image plane. The computation is processed by virtually "peeling" the object space in slices, and by accumulating the result in the image plane. Splatting traditionally classified and shaded the voxels prior to projection, and thus each voxel footprint was weighted by the assigned voxel color and opacity.

As previously discussed, the representation of the data draws from many disciplines such as computer graphics, image processing, art, graphic design, human-computer interface, cognition, and perception. Donna Cox, from the School of Art and Design and the National Center for Supercomputing Applications at the University of Illinois, Urbana-Champaign, understood the potential of bringing scientists and visual design artists together to address the big picture of data visualization. In 1987 Cox developed the concept of "Renaissance Teams," a team of domain experts and visualization experts whose goal was to determine visual representations which both appropriately and instructively presented domain specific scientific data. As Vibeke Sorenson said in a 1989 essay,

"the accumulated knowledge of the fine arts can be extremely useful to Scientific Visualization, a field which will rely more and more on visual skills and ideas. A study of art history can help to gain insights into visual form-giving and unique ways of solving problems which could enhance the scientific research environment in new and unexpected ways."

A similar approach was the basis for the ACCAD and OSGP groups at Ohio State, at Cornell, and at many other visualization centers.

Cox, D. “Renaissance Teams and Scientific Visualization: A Convergence of Art and Science”, Collaboration in Computer Graphics Education, SIGGRAPH 88 Educator’s Workshop Proceedings, August 1-5, 1988, p. 81 – 104.
http://www.ncsa.uiuc.edu/People/cox/

Sorensen, Vibeke, The Contribution of the Artist to Scientific Visualization, 1989
http://visualmusic.org/Biography/Index.html

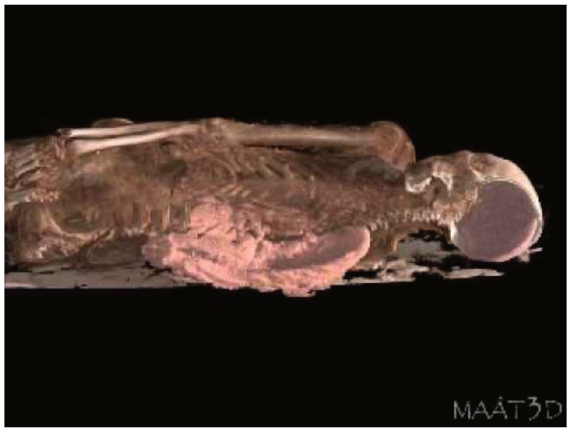
Drebin, R. A., Carpenter, L., and Hanrahan, P. *Volume Rendering*. Computer Graphics 22, 4 (Aug. 1988), 65–74.

Marc Levoy, *Display of Surfaces from Volume Data*, IEEE Computer Graphics and Applications, v.8 n.3, p.29-37, May 1988

Westover, L., Splatting: A Parallel, Feed-Forward Volume Rendering Algorithm. PhD Dissertation, July 1991

David Y. Yun, Hong-Mei C. Garcia, Seong K. Mun, James E. Rogers, Walid G. Tohme, Wayne E. Carlson, Stephen May, and Roni Yagel. “Three Dimensional Volume Visualization in Remote Radiation Treatment Planning”, Proceedings of the IS&T/SPIE Symposium on Electronic Imaging: Science and Technology, Visual Data Exploration and Analysis III, The International Society for Optical Engineering, IS&T/SPIE Proc. 2656, February, 1996.

Movie 18.5 Egyptology: 3D Mummy



https://www.youtube.com/watch?v=Il8gZbD9bkM
Medical Visualization: Egyptology in 3D – A revealing high-resolution look at a 2300-year-old mummy – Renderings of the Champollion mummy in VGStudio Max 2.0 reveal the mummy’s physiology through transparentized wrapping layers (Toulouse France, 2006)

Chapter 19: Quest for Visual Realism

Quest for Visual Realism

As the CG discipline matured, researchers moved from trying to discover fundamental drawing and rendering techniques, and looked to increasing the *complexity*, and in some respects, the *realism* of synthetic images. This chapter highlights some of these researchers and their contributions.



19.1 Particle Systems and Artificial Life



As the CG discipline has matured, researchers have moved from trying to discover fundamental drawing and rendering techniques, and have looked to increasing the complexity, and in some respects, the realism of synthetic images. Hardware has helped in this quest, but the algorithms that are embedded in hardware were first (usually) written and tested in software, later migrating to hardware.

One of the keys to complex realistic images is to represent the laws of nature and the physical environment in such a way that they are reasonably accurate and consistent, yet approximated in such a way as to allow reasonable computation speeds. CG researchers have often resorted to “tricks” that fool the observer into believing that the physical laws are represented … the proof, as some maintain, is in the believability of the image, not necessarily in the accuracy of the representation.

Some of the more important attempts at realistic image synthesis are covered in the next sections. Many of the researchers are leaders in the field, and many have won awards for their contributions to the discipline.

One of the problems with generating highly complex imagery of an organic and realistic nature is the ability to control motion, change of form, dynamics, and surface characteristics of the models in the scene. An early contribution to the solution of this problem was provided by Bill Reeves, in his seminal paper *Particle Systems – A Technique for Modeling a Class of Fuzzy Objects*, presented at SIGGRAPH 82 and published in the April, 1983 ACM Transactions on Graphics.



Bill Reeves

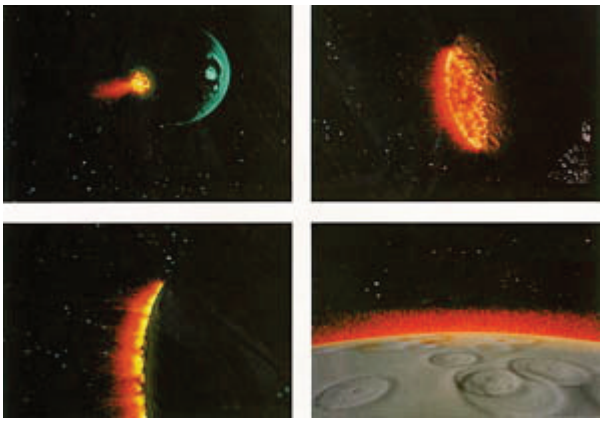
Bill Reeves began his graphics career at the University of Waterloo and at the University of Toronto, where he received his B.S. in math and M.A. and Ph.D. in computer science. In 1980, Reeves joined the computer division of Lucasfilm as project leader of the *systems* group and a member of the computer graphics group. Several years into a career that focused Reeves on the field of animation, he invented the particle systems image synthesis technique that enabled the generation of very complex and detailed images.

From 1982 to 1986, he worked as project leader of the *modeling and animation* group at Lucasfilms. In 1986, Reeves joined Pixar as head of Animation Research and Development. His film credits while at Lucasfilm, Ltd. and Pixar include: *Star Trek II: The Wrath of Khan, Return of the Jedi, Young Sherlock Holmes, Luxo Jr.* (1986 Academy Award nominee), *Red's Dream, Tin Toy and Knickknac* and others. In 1988, Reeves received an Academy Award for Best Animated Short Film for his work as technical director on *Tin Toy*.

A particle system is used to describe techniques for modeling, rendering, and animation of dynamic objects. The system involves a collection of particles, each of which has attributes that directly or indirectly impact the behavior of the particle and/or its neighboring particles. The individual particles can be graphical primitives such as points or lines, but they can also be any geometric entity (birds, stones, snowflakes, water drops, etc.) The other characteristic of a particle system is a random element that controls the actions and characteristics of each particle (eg, position, velocity, color, transparency, etc.) The random element is stochastically controlled, meaning that the randomness has bounds, controlled variance, or some mode of distribution.

For the *Star Trek II – The Wrath of Khan Genesis Effect* scene, Reeves and his colleagues were trying to create a wall of fire spreading out from the point of impact of a projectile on a planetary surface. Every particle in Reeve's system was a single point in space and the wall of fire was represented by thousands of these individual points. Each particle had the following attributes:

- Position in 3D space
- Velocity (speed and direction)
- Color
- Lifetime (how long it is active)
- Age
- Shape
- Size
- Transparency



Frames from the Genesis Effect

Each particle in the system is born (or generated), undergoes some dynamic changes, and dies. Particles in the system are generated semi-randomly within the bounds of some initial object. This space is termed the generation shape of the fuzzy object. Each of the particle's attributes is given an initial value that may be fixed or may be determined by a stochastic process.

The particle undergoes dynamics, meaning the attributes of each of the particles may vary over time. That is, each of the particle attributes can be specified by a parametric equation with time as the parameter and they can be functions of both time and other particle attributes. Each particle has its age and lifetime. Age is the time that the particle has been active (measured in frames from its generation). Lifetime is the maximum amount of time that the particle can live. When the particle age matches it's lifetime it is destroyed. There may also be other criteria for terminating a particle before its lifetime bounds. For example

- If a particle moves out of the viewing area and will not reenter it, it can be killed.
- Particles that impact a "ground plane" burn out and can be killed.
- Some other related attribute reaches a bounding threshold. For example, if the particle color is so close to black or the background color that it will not contribute any color to the final image, it can be killed.

Reeves also used the particle system approach to model bushes in the image *Road to Point Reyes* and trees in the movie *The Adventures of Andre and Wally B.* Each tree was created by using a particle system, and the position of a tree within the forest was also controlled by a particle system. The system can use a "trace" of the trajectory of each particle, and when it dies (eg, at the end of a branch) a leaf can be created.

Gallery 19.1 ILM Particle Systems Images



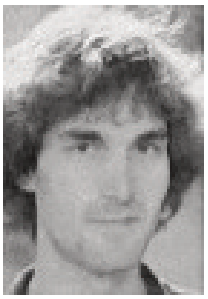
Road to Point Reyes



Plants from Road to Point Reyes – Alvy Ray Smith

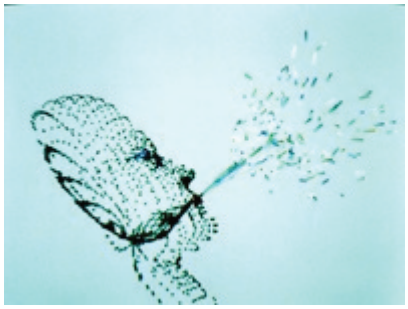


Trees and vegetation from André and Wally B.



Karl Sims

Karl Sims received a B.S. in Life Sciences from MIT in 1984. After working at Thinking Machines Corporation for a year he returned to MIT to study graphics and animation at the Media Laboratory and received his masters in 1987. He then joined the production research team at Whitney/Demos Production in California, and later became co-founder and director of research for Hollywood based Optomystic. He worked at Thinking Machines Corporation as an artist-in-residence and was sometimes employed elsewhere as a part time consultant. He started GenArts, Inc. in Cambridge, Massachusetts, which created special effects software plugins for various packages used for the motion picture industry.



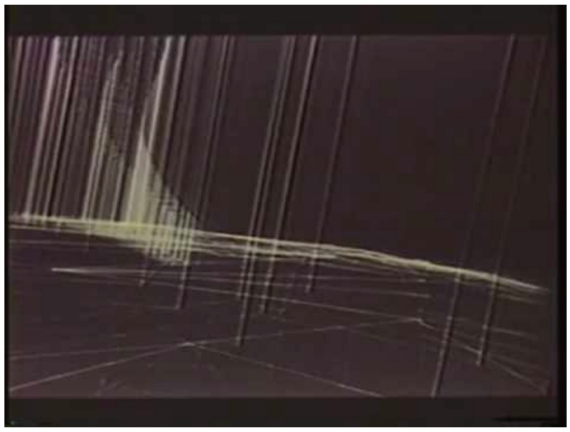
Scene from Particle Dreams

Sims became known for his particle system studies in his short films *Excerpts from Leonardo's Deluge* and *Particle Dreams* (1988). He won the Prix Ars Electronica Golden Nica award two years in a row, in 1991 for *Panspermia*, and in 1992 for *Liquid Selves* and *Primordial Dance*. He has also contributed greatly to the graphics world in the area of artificial evolution and virtual creatures. In 1996, Sims and Gary Oberbrunner created GenArts' Sapphire technology, for use in the creation of visual effects. In 1998 he was awarded a prestigious MacArthur Foundation fellowship.

Sims' company GenArts develops visual effects software for the film, television and video industries. Sims launched GenArts in 1996 out of his barn and just a year later saw his visual effects software used in the making of *Titanic*, the first Oscar winner for the company. The following excerpt is from the company website:

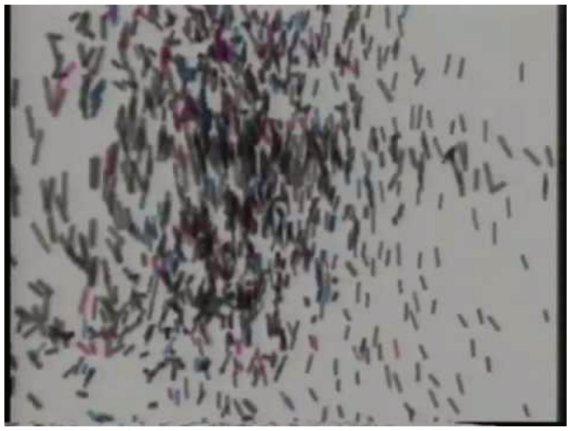
> *"Since the company's founding, GenArts software has been utilized in hundreds of films and in more than 20 Oscar nominated pieces, including Titanic, I Robot, Armageddon, Star Wars Episode I, II and III, The Matrix trilogy, The Lord of the Rings trilogy, Pearl Harbor, Spider Man, Pirates of the Caribbean, Harry Potter and the Prisoner of the Azkaban, Transformers, The Chronicles of Narnia: The Lion, the Witch and the Wardrobe, Iron Man, Benjamin Button, and many more."* http://www.genarts.com/karl/

Movie 19.1 Genesis Sequence



https://www.youtube.com/watch?v=Qe9qSLYK5q4
The making of the Genesis effect from Star Trek II: The Wrath of Khan. Created in 1982 by the Lucasfilm computer graphics division (later to become Pixar).

Movie 19.2 Particle Dreams



https://www.youtube.com/watch?v=tFD4jMMXRbg
Karl Sims movie, Particle Dreams

Movie 19.3 Panspermia (1990)



https://www.youtube.com/watch?v=F4asE2JdSOY
Karl Sims movie, Panspermia

Movie 19.4 Locomotion Studies (1987)
http://www.youtube.com/watch?v=aUdCS1lLiYs

Movie 19.5 Evolved Virtual Creatures – 1994
http://www.youtube.com/watch?v=bBt0imn77Zg

The Adventures of Andre and Wally B.
http://www.youtube.com/watch?v=2doT5t51HGs

"*Particle Systems – A Technique for Modeling a Class of Fuzzy Objects*" B. Reeves, presented at SIGGRAPH 82 and published in the April, 1983 ACM Transactions on Graphics.

"*Artificial Evolution for Computer Graphics*" K.Sims, Computer Graphics (SIGGRAPH 91 proceedings), July 1991, pp.319-328.

"*Particle Animation and Rendering Using Data Parallel Computation*" K.Sims, Computer Graphics (SIGGRAPH 90 proceedings), Aug. 1990, pp.405-413.

Gallery 19.2 Images from Karl Sims



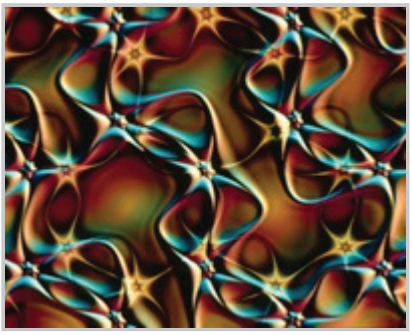
Scene from Panspermia



Scene from Panspermia

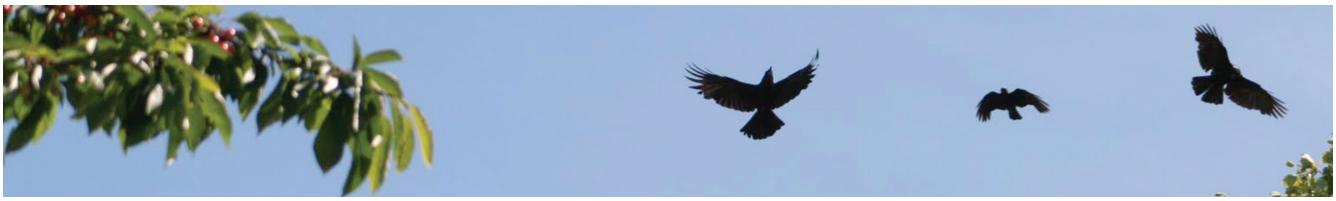


Scene from Panspermia



Scene from Primordial Dance

19.2 Flocking Systems

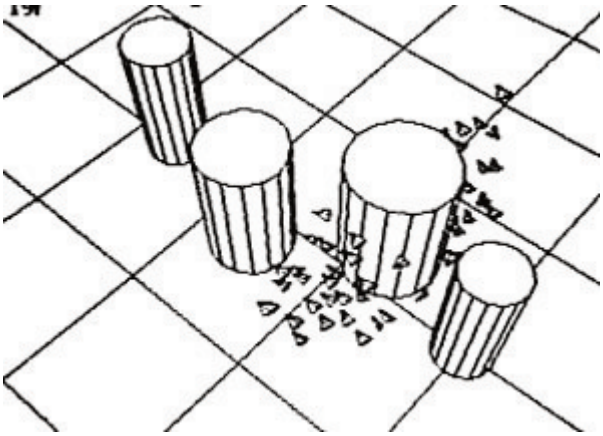




Craig Reynolds

A variation of the particle system was used by **Craig Reynolds** to model the flocking and schooling behavior of birds and fish. In this particle system the particles are used to represent what Reynolds called “boids”. In this case, each particle is an entire polygonal object rather than a graphical primitive, each particle has a local coordinate system, and there are a fixed number of particles that are not created or destroyed. The attributes which control the boids behavior is dependent on external as well as internal conditions, allowing a boid particle to react to what other particles are doing around it. Some characteristics of this system include:

- Collision avoidance – a boid is constrained from colliding with other boids or obstacles;
- Velocity matching – each boid attempts to go the same speed and direction as neighboring boids;
- Flock centering – each boid attempts to stay close to nearby flockmates.



Test Scene from Boids

According to Reynolds:

> Typical computer animation models only the shape and physical properties of the characters, whereas behavioral or character-based animation seeks to model the behavior of the character. The goal is for such simulated characters to handle many of the details of their actions, and hence their motions. These behaviors include a whole range of activities from simple path planning to complex "emotional" interactions between characters. The construction of behavioral animation characters has attracted many researchers, but it is still a young field in which more work is needed.

Reynolds' 1986 computer model of coordinated animal motion was based on three dimensional computational geometry. The flocking model placed an individual "boid" in a flock, and determined the motion path using the steering behaviors that were based on the positions and velocities nearby flockmates:

- Separation: steer to avoid crowding local flockmates
- Alignment: steer towards the average heading of local flockmates
- Cohesion: steer to move toward the average position of local flockmates



Scene from Stanley and Stella: Breaking the Ice

Each boid has direct access to the whole scene's geometric description, but it needs to react only to flockmates within a certain small neighborhood around itself. The neighborhood is characterized by a distance (measured from the center of the boid) and an angle, measured from the boid's direction of flight. Flockmates outside the local neighborhood are ignored.

Reynolds produce a short film for the SIGGRAPH 87 electronic theatre called *Stanley and Stella in: Breaking the Ice*. to demonstrate the basic flocking and schooling algorithms in his system, which he called BOIDS. The film was made in conjunction with Symbolics and Whitney/Demos Productions.



Scene from Eurhythmy

Reynolds flocking algorithm was not the first such algorithm. For the famous film *Eurhythmy* produced at Ohio State, Susan Amkraut implemented what she referred to as a "force-field" flocking algorithm. She describes her approach in an interview with later collaborator Paul Kaiser:

> Yes, I'd started working on the problem of flocking. Whereas Michael's [Girard] project [at Ohio State] was to look at the human body in motion, mine was to take a mathematical algorithm and to see where it could lead. I'd begun by animating particles using force-fields in 3D. These force-fields would attract, or repel, or shape the movement of the

particles. So, for example, I could have a sink that drew all the particles in, or a source they'd funnel out of, or even a spiral they'd fly around. I soon saw how this could lead to an elegant solution for flocking.

The problem posed by flocking is this: you have multiple creatures who don't want to run into each other, but also want to stay very close together — and they have to avoid hitting any external obstacles as well. Algorithms had been developed in which a lead bird guided the flock. But real flocks behave in a more interesting fashion: they have no leader. So, neither did my algorithm, which worked like this. I put a little force-field around every bird, so that if any other bird got near, it was told to go away. And of course each bird had a corresponding attraction field, so that if the other bird got too far away, it was told to come closer. So every bird at every frame of the animation considers every force-field around it, and moves accordingly.

It's a difficult algorithm to work with because you can't tell where you are at any given point in time unless you know where you started and have computed all the way back up from there. My interest in this went beyond wanting to simulate actual flocks. I wanted to create a flock of birds all flying realistically as individuals, but flying collectively in patterns that could never happen in the real world.

As Reynolds points out on his web site, since 1987 there have been many other applications of the boids model in the realm of behavioral animation. The 1992 Tim Burton film *Batman Returns* was the first. It contained computer simulated bat swarms and penguin flocks which were created with modified versions of the original boids software developed at Symbolics. Andy Kopra (then at VIFX, which later merged with Rhythm & Hues) produced realistic imagery of bat swarms. Andrea Losch (then at Boss Films) and Paul Ashdown created animation of an "army" of penguins marching through the streets of Gotham City.

A similar approach was used to produce the famous Wildebeest stampede in the Disney movie *The Lion King*. According to the film notes at *http://www.lionking.org/text/FilmNotes.html*



Wildebeest stampede

For the pivotal scene in the film where Scar enacts his plan to do away with his royal relatives, Mufasa and Simba, directors Allers and Minkoff wanted to create something with the same visual impact as the dramatic events that were unfolding. The script called for thousands of stampeding wildebeests to pour over the hilltop into the gorge below. Feature Animation's CGI (Computer Generated Imagery) department was called upon to help pull off this amazing feat and to enhance the emotional impact of the scene. Five specially trained animators and technicians in this department spent over two years creating the impressive 2-1/2 minute sequence, which represents a new level of sophistication for the art form and a dramatic highlight for the film.

Starting with a 2-dimensional model sheet and some conventional hand-drawn rough animation, created by supervising animator Ruben Aquino, Johnston and his CGI team were able to generate 3-dimensional representations of a wildebeest inside the computer. Once this digitized computer version existed, the camera could be placed anywhere to allow different angles during the course of a scene.

"Since the scene called for a stampede, we had to come up with a way that our animators could control the behavior of herds of wildebeests without having them bump into each other," says Johnston. "We developed a simulation program that would allow us to designate leaders and followers within each group. We were also able to individualize and vary the movement of each animal within a group to give them a certain random quality.

Effectively they could all be doing different things with the library of behavior including slow and fast gallops, various head tosses and even a few different kinds of leaps."

In the end, the hand-drawn animation of Simba and Mufasa was composited with the CGI wildebeest stampede and the film's other hand-drawn elements (backgrounds and effects). "The object is to make the wildebeests look like the other characters in the film," says Johnston. "We don't want them to stand out. We just want a dramatic effect."



Scene from Titanic

The flocking algorithms developed by Reynolds and others have advanced significantly, and variations on the same approach have been used (coupled with new technologies such as motion capture) to generate crowds and large numbers of animated characters for motion pictures. In the movie *Sharkslayers*, large schools of fish are animated. There are armies in *Star Wars, The Mummy, and Lord of the Rings*, colonies of ants in *Antz*, insects in *A Bug's Life*, and passengers on the *Titanic*. Production companies such as PDI and ILM have developed their own approach to crowd control, and software packages like Houdini and Character Studio have included crowd animation components.

Several articles by Barbara Robertson of Computer Graphics World have dealt with crowd animation, including *Crowd Control* in the February, 1998 issue, *Faces and Crowds* in the July 1998 issue, *A Bug's Eye View* in the November 1998 issue, and more recently *The Two Towers* (February 2003).



Scene from Two Towers

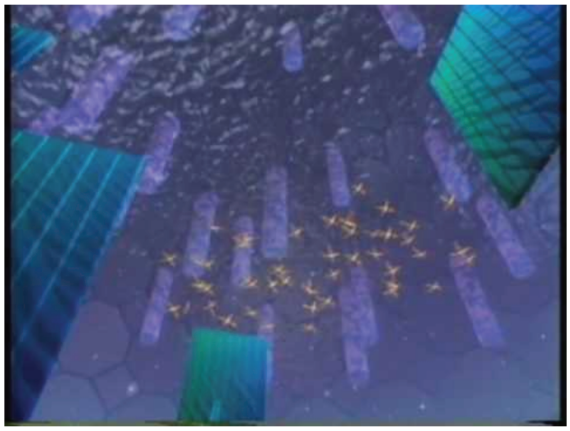
Movie 19.6 Eurhythmy Motion Studies (1985)



https://www.youtube.com/watch?v=qVcyttQbKP0

Produced at Ohio State by Michael Girard and Susan Amkraut, it uses Amkraut's flocking behavior for the birds animation

Movie 19.7 Stanley and Stella in Breaking the Ice



https://www.youtube.com/watch?v=3bTqWsVqyzE
Animated by Phillipe Bergeron using Craig Reynolds behavioral animation techniques (1987)

Flocks, Herds, and Schools: A Distributed Behavioral Model, Craig Reynolds, Computer Graphics, 21(4), July 1987, pp. 25-34
http://www.cs.toronto.edu/~dt/siggraph97-course/cwr87/

Comprehensive review of flocking literature and contributions:
http://www.red3d.com/cwr/boids/

19.3 Physical-based Modeling



These approaches to defining environments and actions in the “physical world” defined by a computer graphics-based synthetic approach can be considered part of a collective family of algorithmic approaches called physically-based modeling. According to **Demetri Terzopolous**, one of the pioneers of this approach, in a SIGGRAPH 89 panel discussion:

Physically-based techniques facilitate the creation of models capable of automatically synthesizing complex shapes and realistic motions that were, until recently, attainable only by skilled animators, if at all. Physically-based modeling adds new levels of representation to graphics objects. In addition to geometry — forces, torques, velocities, accelerations, kinetic and potential energies, heat, and other physical quantities are used to control the creation and evolution of models. Simulated physical laws govern model behavior, and animators can guide their models using physically-based control systems. Physically-based models are responsive to one another and to the simulated physical worlds that they inhabit.

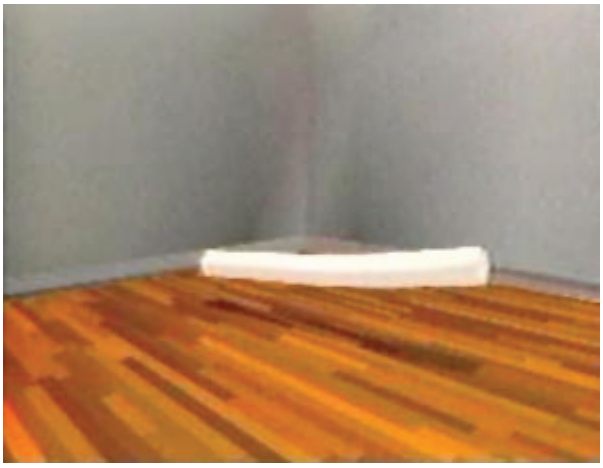
Centers of activity in the physically-based modeling and animation area included Ohio State (Dave Haumann, James Hahn, Michael Girard and John Chadwick), CalTech (Al Barr, Kurt Fleischer, Ronen Barzel, John Platt) Carnegie Mellon (Andrew Witkin and David Baraff) and Apple Computer (Gavin Miller, Michael Kass, Lance Williams, Ned Greene and others) and later at Pixar (Baraff, Witkin, Fleischer, Barzel and Kass).

Ohio State University



Rigid Body Dynamics – James Hahn

Two early physically based modeling research experiments were done at Ohio State by Dave Haumann and James Hahn. Hahn's 1988 work created an animation system that gave the animator control over the simulation of dynamic interaction between rigid objects, taking into account physical characteristics of friction, mass, motion, elasticity and moments of inertia. His system effectively combined kinematics and dynamics in a computationally efficient method. Hahn went on to continue his research as the Director of The Institute for Computer Graphics at The George Washington University.



Flexible Bodies – Dave Haumann

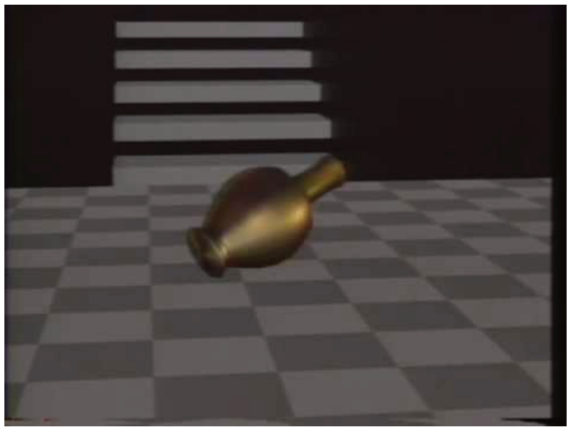
Haumann's work with physically-based simulations used simple mass-spring models, through which he could model bridge cables and tanzan vines. He added vector fields to simulate flags and curtains as well. These effects were shown in a 1988 movie that accompanied a paper in SIGGRAPH. His research was used by Chris Wedge in a 1989 movie produced at Ohio State called *Balloon Guy*. Haumann went to IBM, and experimented with effects for demonstrating the shattering of a physical object. He then experimented with time-varying vector fields, including vortices, sources, sinks and uniform fields for a movie that simulated leaves blowing in these fields. He then expanded his model of leaves, picked a leaf shape that floated nicely, and showed a movie illustrating his work. After IBM he went to Pixar, where he worked on the Pixar short *Geri's Game*.

Hahn, James. "*Realistic Animation of Rigid Bodies*", Computer Graphics, Proceedings SIGGRAPH 88, Association for Computing Machinery (ACM), Vol. 22, No. 4 (August 1988), pp. 299-308

Haumann, D., "Modeling the Physical Behavior of Flexible Objects", in Topics in Physically-Based Modeling, SIGGRAPH Tutorial 17 Notes, 1987.

Jakub Wejchert , David Haumann, Animation aerodynamics, ACM SIGGRAPH Computer Graphics, v.25 n.4, p.19-22, July 1991

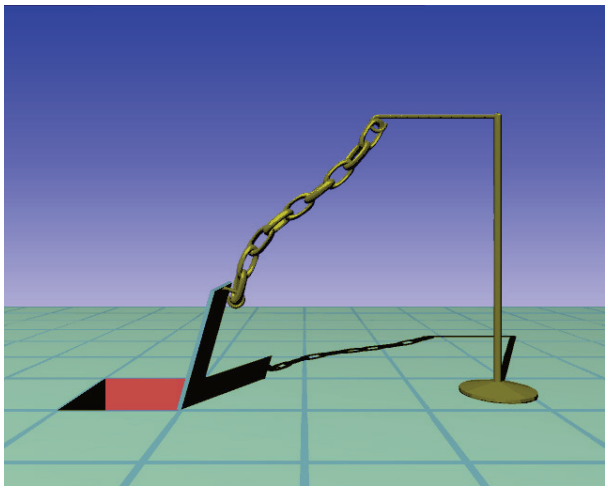
Movie 19.8 Rigid Body Dynamics



https://www.youtube.com/watch?v=AmFYMbJ0Eew
Produced at Ohio State by James Hahn (1987)

Cal Tech

Al Barr advised several important researchers at the Graphics Group at Cal Tech. His students included Ronen Barzel (Pixar), John Platt (Microsoft), David Kirk (NVIDIA), Kurt Fleischer (Pixar) and others. Together with **Andrew Witkin**, Barr coordinated several sessions related to physically-based modeling for the SIGGRAPH courses program (1987-1991), as well as panels and papers on the topic. The list of papers below shows the influence of the CalTech researchers on this area of graphics. A complete list of their publications can be found on their web site at
http://www.gg.caltech.edu/publications.html#papers



Pandora's Chain – Al Barr – CalTech

Dynamic Constraints: A New Paradigm for Computer Graphics Modeling, State of the Art in Image Synthesis, ACM SIGGRAPH 1986

Elastically Deformable Models, with D. Terzopoulos, J. Platt and K. Fleischer, Computer Graphics(21), ACM SIGGRAPH, 1987.

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Energy Constraints on Parameterized Models, with A. Witkin and K. Fleischer, Computer Graphics(21), ACM SIGGRAPH, 1987.

Ronen Barzel, A Structured Approach to Physically-Based Modeling, Ph.D. Thesis, California Institute of Technology, 1992

Ronen Barzel, Controlling Rigid Bodies with Dynamic Constraints, Master's Thesis, Caltech-CS-TR-88-19, California Tech, 1988

Demetri Terzopoulos received his university education at McGill University (B.Eng. 1978, M.Eng. 1980) and MIT (PhD 1984). He does pioneering work in artificial life, an emerging field that cuts across computer science and biological science. He devises computer models of animal locomotion, perception, behavior, learning and intelligence. Terzopoulos and his students have created artificial fishes, virtual inhabitants of an underwater world simulated in a powerful computer. These autonomous, lifelike creatures swim, forage, eat and mate on their own. Terzopoulos has also done important work on human facial modeling. He has produced what is widely recognized as the most realistic biomechanical model of the human face to date. Expressive synthetic faces are useful in entertainment and human-computer interaction, but they can also play a role in planning reconstructive facial surgery, as well as in automated face recognition and teleconferencing systems. Terzopoulos is widely known as the inventor of deformable models, a family of shape modeling algorithms that have bridged the fields of computer vision and computer graphics and have opened up new avenues of research in medical imaging and computer-aided design.



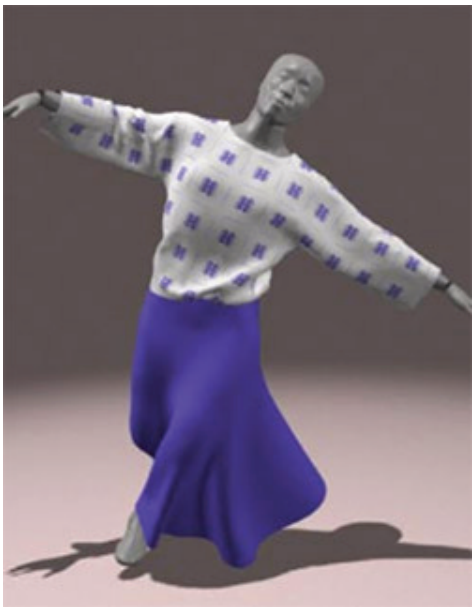
Terzopoulos facial expressions

ACM SIGGRAPH recognized **Andrew Witkin** for his pioneering work in bringing a physics-based approach to computer graphics with the 2001 Computer Graphics Achievement Award. Witkin's papers on active contours (snakes) and deformable models, variational modeling, scale-space filtering, space time constraints, and dynamic simulation are considered landmarks that have been inspirational to others and have shaped the field in such different areas as image analysis, surface modeling, and animation.

He received his Ph.D. at the Massachusetts Institute of Technology in the psychology department. In the early

1980s, the vision and graphics research communities were largely disjoint. Witkin was one of the first to bridge the divide in a series of papers that included his 1987 prize winning paper *Constraints on Deformable Models: Recovering 3D Shape and Non-rigid Motion* and *Snakes: Active Contour Models*, both co-authored with Michael Kass and Demetri Terzopoulos. These papers popularized the idea that computer vision techniques could provide interactive "power assists" to a human operator creating computer graphics models.

While still at Schlumberger, and subsequently as a professor at Carnegie Mellon University, Witkin did notable work on the use of physically-based modeling techniques not only for animating rigid or deformable objects, but also as an interaction technique for a range of problems including constrained geometric modeling and camera control (with Michael Gleicher) and visualization of implicit surfaces (with Paul Heckbert). In 1992, with Michael Kass, Witkin won a Golden Nica from Ars Electronica for his use of physically based modeling of reaction-diffusion equations to synthesize organic looking textures. In 1988 Witkin, with Michael Kass, introduced the idea of using control theory in computer graphics with their *Spacetime Constraints* paper and showed that optimization could be used to direct physically-based character animation.

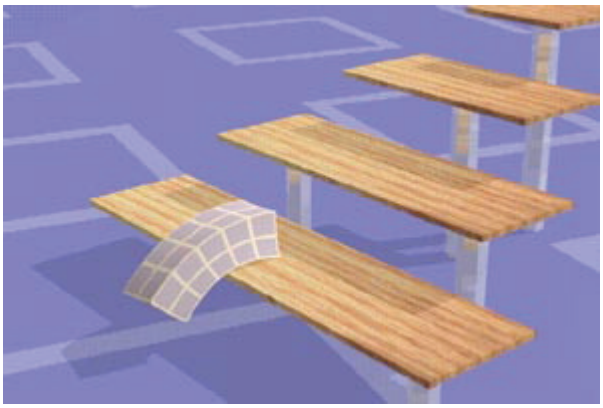


Flowing cloth was difficult to ?describe algorithmically

Witkin then became interested in the very difficult problem of clothing simulation. With David Baraff at Carnegie Mellon University, Witkin developed the clothing simulator which formed the basis of Maya Cloth, and which was used in the production of *Stuart Little*, among other films. With David Baraff and Michael Kass at Pixar Animation Studios, Witkin developed the clothing and hair simulator used in the Pixar/Disney film *Monsters, Inc.*

Monsters Inc. marked Pixar's first extensive use of physical simulation in a feature film. Pixar animators directly controlled the movements of the characters' bodies and faces, but much of their hair and clothing movement was computed using simulations of Newtonian physics. Physical simulation allowed a degree of realism of motion that would not have been possible with traditional methods. Nonetheless, adding this type of simulation into the Pixar production pipeline sometimes caused surprising and amusing results. One of the key developments that allowed clothing simulation to go smoothly during the production was a set of algorithms for untangling simulated clothing when the animation process distorted it significantly. The algorithms allowed the simulator to handle a range of non-physical situations like character interpenetrations without producing unpleasant visual artifacts.

David Baraff joined Pixar Animation Studios in 1998 as a Senior Animation Scientist in Pixar's research and development group. Prior to his arrival at Pixar, he was an Associate Professor of Robotics, and Computer Science at Carnegie Mellon University. Baraff received his Ph.D. in computer science from Cornell University in 1992, and his Bs.E. in computer science from the University of Pennsylvania in 1987. Before and during his graduate studies, he also worked at Bell Laboratories' Computer Technology Research Laboratory doing computer graphics research, including real-time 3D interactive animation and games. In 1992, he joined the faculty of Carnegie Mellon University. In 1995, he was named an ONR Young Investigator.



Dynamic simulation of non-penetrating objects – David Baraff

Apple Advanced Technology Group

Several important contributors to the computer graphics discipline spent time with the research lab at Apple Computer. The Apple Advanced Technology Group (ATG) started in 1986 and worked on many fundamental issues, including human computer interaction, video compression, handwriting analysis, speech synthesis and advanced computer graphics. The group included such CG notables as Eric Chen, Gavin Miller, Michael Kass, Ned Greene, Lance Williams, Frank Crow, David Em, Larry Yaeger, Eric Hoffert, Pete Litwinowicz, Ken Turkowski, Michael Gleicher, and others. They contributed several papers and animations to the physically based modeling community, including computational fluid flow, mass-spring solutions, and dynamics.



Scene from Geri's Game

Michael Kass held a research position at Schlumberger Palo Alto Research before joining the ATG. He then left to become a Senior Scientist at Pixar Animation Studios in 1995. He received his B.A. from Princeton in 1982, his M.S. from M.I.T. in 1984, and his PhD from Stanford in 1988. Kass received numerous awards for his research on physically-based methods in computer graphics and computer vision including several conference best paper awards, the Prix Ars Electronica for the image *Reaction Diffusion Texture Buttons*, and the Imagina Grand Prix for the animation *Splash Dance*, a film he produced with Gavin Miller. Kass published widely, and two of his notable papers dealt with constraint-based dataflow and rapid, stable fluid dynamics. He also contributed to cloth and hair simulation, particularly for *Geri's Game* and *Monsters Inc*.

Gavin Miller contributed to the animated shorts *Splash Dance* (with Kass), *The Audition* (with Eric Chen), *Flow* (with Ned Greene),and *Her Majesty's Secret Serpent* (with Kass and Lance Williams). He worked on issues of motion dynamics (of snakes and worms), viscous fluid animation, terrain mapping, flexible body motion, and other areas of natural phenomena representation. He received his PhD at Cambridge University and was at Alias before joining ATG. He left to join Adobe, where he worked on Acrobat 3D. The image above shows his fluid flow and his accessibility shading research, with the left model of him and the right of his co-contributor Ned Greene.



Gavin Miller and Ned Greene modeled and rendered with fluid flow simulation

Ned Greene graduated from UC-Santa Cruz after working from 1980 to 1989 at NYIT and later at ATG from 1989 to 1996. He worked with Kass and Miller modeling scenes for several animations (*Flow* – 1993, *Splash Dance* – 1990, *The Audition* – 1990), and also on visibility algorithms for rendering complex scenes. Greene left ATG to go to HP and NVIDIA.

Movie 19.9 Flow

https://osu.pb.unizin.org/graphicshistory/wp-content/uploads/sites/45/2017/04/FLOW320-2.m4v

Gavin Miller & Ned Greene – Apple Advanced Technology Group

Movie 19.10 Her Majesty's Secret Service
Apple Technology Group – Gavin Miller and Michael Kass (1989
https://www.youtube.com/watch?v=qtJmulx3c8E

Movie 19.11 Natural Phenomena
Alias and SGI – Gavin Miller (1988)
https://www.youtube.com/watch?v=gL7YiApRvFY

David Baraff and Andrew Witkin. Dynamic simulation of non-penetrating flexible bodies. Computer Graphics, 26:303-308, 1992. Proc. Siggraph ’92.

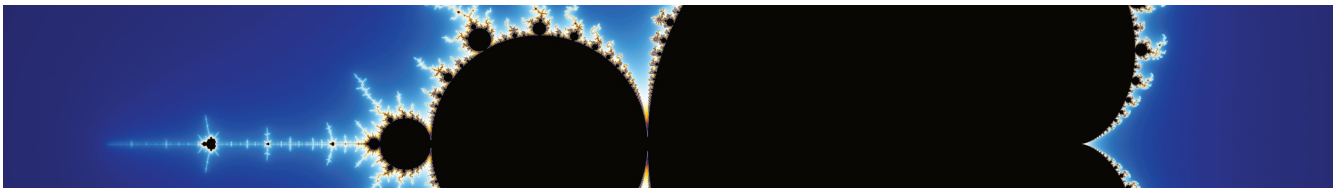
Andrew Witkin and Michael Kass. Reaction-diffusion textures. Computer Graphics, 25(3), July 1991. Proc. Siggraph 91.

Miller, Gavin S. P., “Efficient Algorithms for Local and Global Accessibility Shading”, Proceedings of SIGGRAPH ’94.

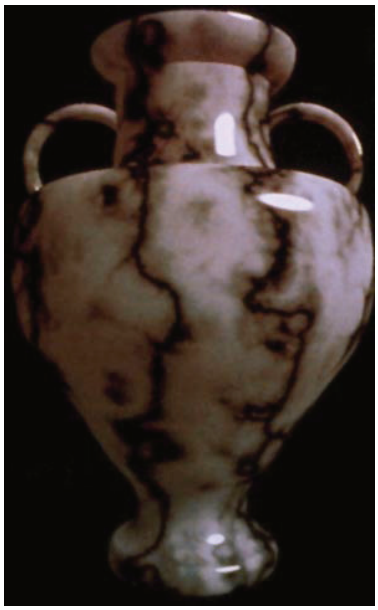
Greene, Ned, Michael Kass, Gavin Miller, “Hierarchical Z-Buffer Visibility”, Proceedings of SIGGRAPH ’93.

David Baraff, A. Witkin and M. Kass, “Untangling cloth,” ACM Trans. Graph. 22(3): 862-870 (2003).

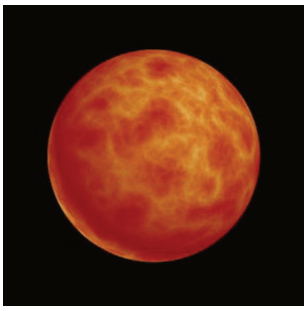
19.4 Noise functions and Fractals



Ken Perlin received a B.A. in theoretical mathematics from Harvard University in 1979 and his Ph.D. in Computer Science from New York University in 1986. Perlin started his graphics career as the System Architect for computer generated animation at MAGI (Mathematical Applications Group, Inc.) in Elmsford, NY. While at MAGI he worked on the movie TRON and began thinking about what would be his **noise functions** and how they could be used to efficiently create textures for use in complex images. Between 1984 and 1987 Perlin was Head of Software Development at R/Greenberg Associates in New York. He then became a professor in the Media Research Laboratory in the Department of Computer Science at New York University and served as the co-Director of the NYU Center for Advanced Technology. According to his bio on the NYU site, he has served on the Board of Directors of the New York chapter of ACM/SIGGRAPH, and on the Board of Directors of the New York Software Industry Association. His research interests include graphics, animation, and multimedia. In 2002 he received the NYC Mayor's award for excellence in Science and Technology and the Sokol award for outstanding Science faculty at NYU. In 1991 he received a Presidential Young Investigator Award from the National Science Foundation.



Perlin Noise Function Vase



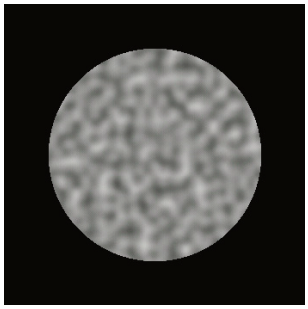
Perlin Noise Functions

In 1997 Perlin won an Academy Award for Technical Achievement from the Academy of Motion Picture Arts and Sciences for his *noise and turbulence procedural texturing techniques*, which are widely used in feature films and television.

As Perlin said in a lecture at the Game Developers Conference HardCore seminars titled *Making Noise* [1] in 1999,

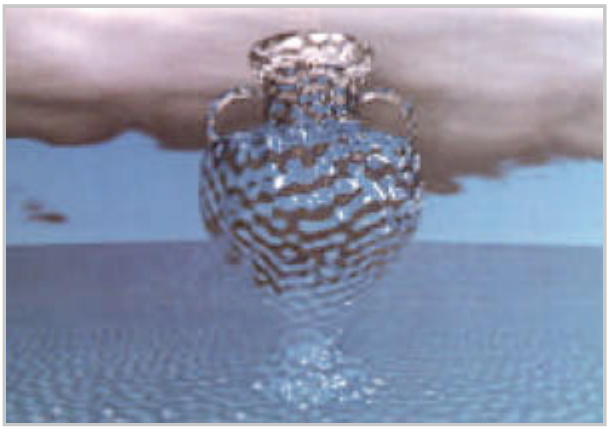
"The first thing I did in 1983 was to create a primitive space-filling signal that would give an impression of randomness. It needed to have variation that looked random, and yet it needed to be controllable, so it could be used to design various looks. I set about designing a primitive that would be "random" but with all its visual features roughly the same size (no high or low spatial frequencies).

I ended up developing a simple pseudo-random "noise" function that fills all of three dimensional space (a slice of the 3D is shown here). In order to make it controllable, the important thing is that all the apparently random variations be the same size and roughly isotropic. Ideally, you want to be able to do arbitrary translations and rotations without changing its appearance too much."



Perlin Noise Functions

Perlin modified his noise functions so that he could make naturally looking textures using controllable mathematical expressions, which he integrated into shaders. He later expanded the noise to generate 3D models, a process he dubbed *Hypertexture* in a 1989 paper. A tutorial about Perlin noise, with code, can be found on the scratchapixel.com tutorial site.



Perlin Noise Functions

1. This site is currently offline, but can be found in web archive at https://web.archive.org/web/20160303232627/http://www.noisemachine.com/talk1/



Perlin Noise Functions

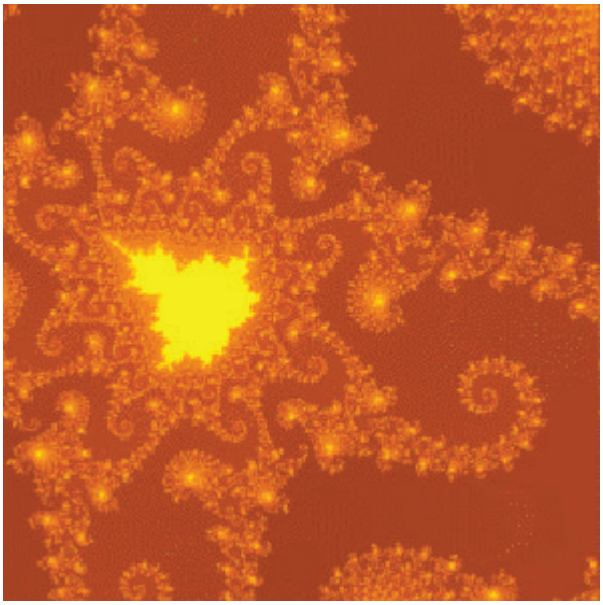


Benoit Mandelbrot

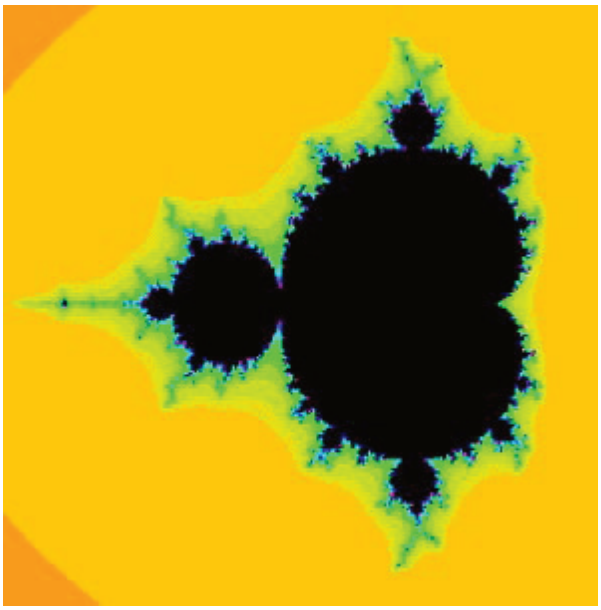
Benoit Mandelbrot is largely responsible for the present interest in **fractal** geometry, which has found its way into the fibre of computer graphics. He showed how fractals can occur in many different places in both mathematics and elsewhere in nature. In 1958, after a stint at the Institute for Advanced Study, he came to the United States permanently and began his long standing collaboration with IBM as an IBM Fellow at their Thomas J. Watson Research Laboratory in Yorktown Heights.

The IBM Watson laboratory provided Mandelbrot the opportunity to research many different concepts and approaches to looking at nature, in his words "an opportunity which no university post could have given me." After retiring from IBM, became a professor at Yale University, where he received tenure and served as the Sterling Professor of Mathematical Sciences.

He had been introduced at an early age to the mathematical concepts of the mathematicians Gaston Julia and his rival Pierre Fatou, whose contributions to the mathematics discipline were important but pretty much forgotten because of their rivalry until Mandelbrot revived a discussion of them. Mandelbrot had been working in other areas of scientific concepts, not in math, until he started rethinking about some areas of geometry and how they could provide a lens for visualizing science. This interest in geometric concepts brought him back to some of the ideas of Julia, in particular the one unifying aspect of certain geometries that was the concept of self-similarity. In the mid-1970s he coined the word "fractal" as a label for the underlying objects, since he observed that they had fractional dimensions.



Fractals



Fractals

A fractal is a rough or fragmented geometric shape that can be subdivided in parts, each of which is (at least approximately) a reduced-size copy of the whole. Fractals are generally self-similar and independent of scale, that is they have similar properties at all levels of magnification or across all times. Just as the sphere is a concept that unites physical objects that can be described in terms of that shape, so fractals are a concept that unites plants, clouds, mountains, turbulence, and coastlines, that do not correspond to simple geometric shapes.

According to Mandelbrot,

> "I coined fractal from the Latin adjective fractus. The corresponding Latin verb frangere means "to break" or to create irregular fragments. It is therefore sensible – and how appropriate for our needs – that, in addition to "fragmented" (as in fraction or refraction), fractus should also mean "irregular," both meanings being preserved in fragment."
> (The *Fractal Geometry of Nature*, page 4.)

He gives a mathematical definition of a fractal as a set for which the **Hausdorff-Besicovich dimension** strictly exceeds the topological dimension.

With the aid of computer graphics, Mandelbrot was able to show how Julia's work is a source of some of the most beautiful fractals known today. To do this he had to develop not only new mathematical ideas, but also he had to develop some of the first computer programs to print graphics. An example fractal is the Mandelbrot set (others include the Lyapunov fractal, Julia set, Cantor set, Sierpinski carpet and triangle, Peano curve and the Koch snowflake).

To graph the Mandelbrot set a test determines if a given number in the complex number domain is inside the set or outside the set. The test is based on the equation $Z = Z^2 + C$ where C represents a constant number, meaning that it does not change during the testing process. Z starts out as zero, but it changes as the equation is repeatedly iterated. With each iteration a new Z is created that is equal to the old Z squared plus the constant C.

The actual value of Z as it changes is not of interest per se, only its magnitude. As the equation is iterated, the magnitude of Z changes and will either stay equal to or below 2 forever (and will be part of the Mandelbrot set), or it will eventually surpass 2 (and will be excluded from the set). To create the visual representation a color is assigned to a number if it is not part of the Mandelbrot set. The actual color value is determined by how many iterations it took for the number to surpass 2.

Mandelbrot's work was first described in his book *Les Objets Fractals, Forn, Hasard et Dimension* (1975) and later in *The Fractal Geometry of Nature* (1982).

http://en.wikipedia.org/wiki/Fractal

Loren Carpenter was employed at Boeing in Seattle when he decided he wanted to pursue a career in the evolving graphics film production industry. As an engineer at Boeing, Carpenter worked on problems related to

the creation of high-quality *renderings of free-form surfaces*. He was also responsible for the development of algorithms for the use of fractal geometry as a tool for creating complex scenes for graphic display.

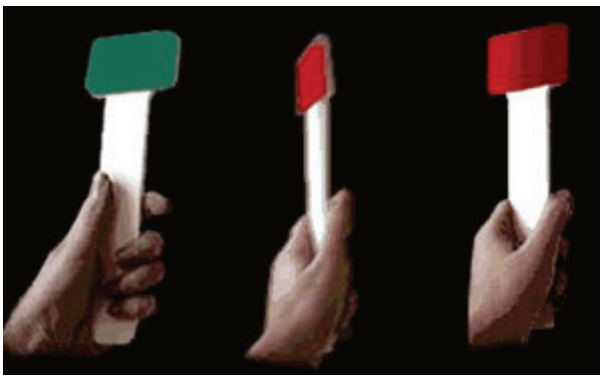


Scene from Vol Libre

In 1980 Carpenter used the fractal concept to create mountains for his film *Vol Libre*, which generated widespread interest in the possibilities that this approach promised. His technical contributions, along with the seminal work with fractals, resulted in a position with Lucasfilm's Computer Division in 1981 (see the sidebar at the end of this section). He recreated the fractal mountains used in *Vol Libre* as part of the *Genesis Demo* for *Star Trek II: The Wrath of Khan*. Another of his contributions, the A-buffer hidden surface algorithm, was central to the systems used by many production companies to create images for television and motion pictures.

He is the author of numerous fundamental papers in computer image synthesis and display algorithms. His research contributions include **motion blur**, fractal rendering, **scan-line patch rendering**, the **A-buffer**, distributed ray tracing and many other algorithmic approaches to image making. He holds several patents both personally and through Pixar, and his technical awards include the third SIGGRAPH Technical Achievement Award in 1985.

In 1986, when Lucasfilm's Computer Division spun off to form Pixar, Loren became Chief Scientist for the company. In 1993, Loren received a Scientific and Technical Academy Award for his fundamental contributions to the motion picture industry through the invention and development of the RenderMan image synthesis software system. RenderMan has been used by many computer-generated films, including use by Lucasfilm's Industrial Light and Magic to render the dinosaurs in Jurassic Park.



Cinematrix Wand

Carpenter also patented an interactive entertainment system which, through the use of simple retroreflectors, allows large audiences to play a variety of games together either as competing teams or unified toward a common goal, such as flying a plane. Enthusiastic audiences have shown that many types of people find this new method of communicating fun and exciting. Concurrently with his leadership of Pixar, Loren and his wife Rachel founded Cinematrix to explore the intersection of computers and art. Cinematrix's Interactive Entertainment Systems division is focusing on the development of an interactive audience participation technology that enables thousands of people to simultaneously communicate with a computer, making possible an entire new class of human-computer interaction.



Reflectors used by audience to control motion

http://www.cinematrix.com/

Other people involved in using fractals as a basis for their work in image-making include Richard Voss, Ken Musgrave, Michael Barnsley, Melvin Prueitt (and high school and college students all over the world!)



Loren Carpenter, Rob Cook and Ed Catmull – And the Oscar Goes to… (IEEE Spectrum, April 2001)

Movie 19.12 Vol Libre



https://vimeo.com/5810737

1980 film by Loren Carpenter, created while he was at Boeing, and shown to attendees of the 1980 SIGGRAPH conference

The following account is from the book *Droidmaker- George Lucas and the Digital Revolution*, by Michael Rubin.

> Fournier gave his talk on fractal math, and Loren gave his talk on all the different algorithms there were for generating fractals, and how some were better than others for making lightning bolts or boundaries. "All pretty technical stuff," recalled Carpenter. "Then I showed the film."
>
> He stood before the thousand engineers crammed into the conference hall, all of whom had seen the image on the cover of the conference proceedings, many of whom had a hunch something cool was going to happen. He introduced his little film that would demonstrate that these algorithms were real. The hall darkened. And the Beatles began.
>
> Vol Libre soared over rocky mountains with snowy peaks, banking and diving like a glider. It was utterly realistic, certainly more so than anything ever before created by a computer. After a minute there was a small interlude demonstrating some surrealistic floating objects, spheres with lightning bolts electrifying their insides. And then it ended with a climatic zooming flight through the landscape, finally coming to rest on a tiny teapot, Martin Newell's infamous creation, sitting on the mountainside.
>
> The audience erupted. The entire hall was on their feet and hollering. They wanted to see it again. "There had never been anything like it," recalled Ed Catmull. Loren was beaming.
>
> "There was strategy in this," said Loren, "because I knew that Ed and Alvy were going to be in the front row of the room when I was giving this talk." Everyone at SIGGRAPH knew about Ed and Alvy and the aggregation at Lucasfilm. They were already rock stars. Ed and Alvy walked up to Loren Carpenter after the film and asked if he could start in October.
> *(Available as an eBook from the iTunes store)*

Ken Perlin, *An image synthesizer*, SIGGRAPH 1985, pp. 287 – 296.

Ken Perlin and Eric Hoffert, *Hypertexture*, SIGGRAPH 1989, pp. 253 – 262.

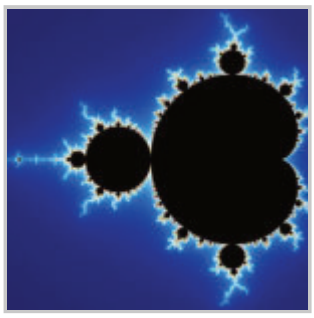
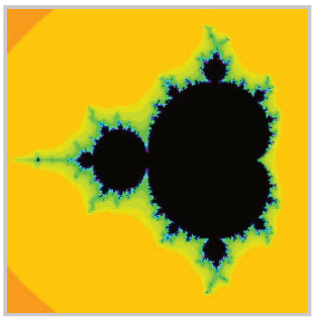
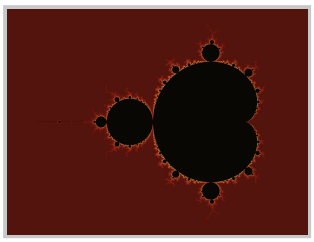
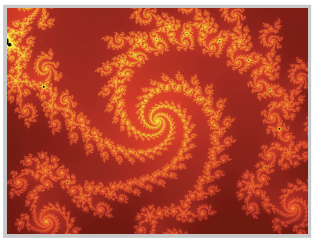
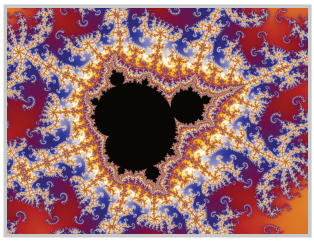
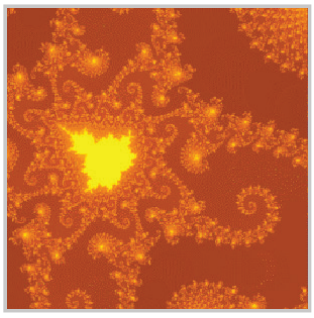
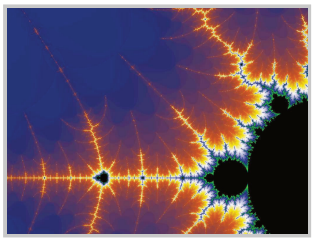
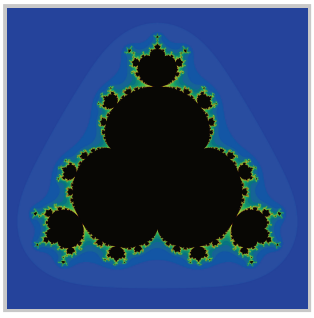
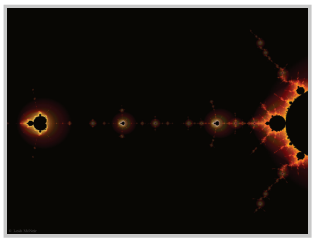
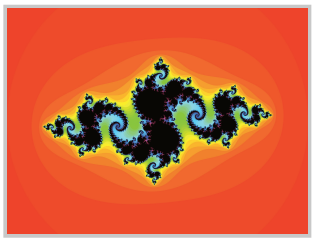
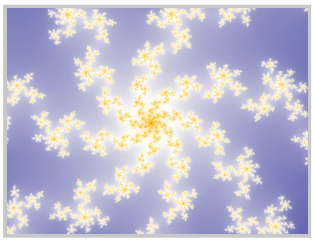
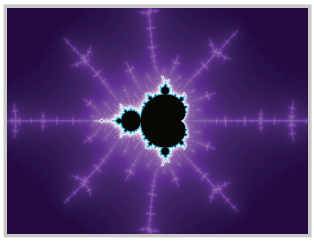
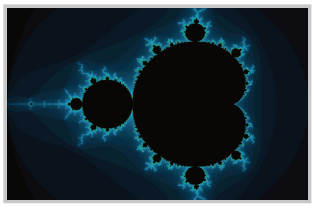
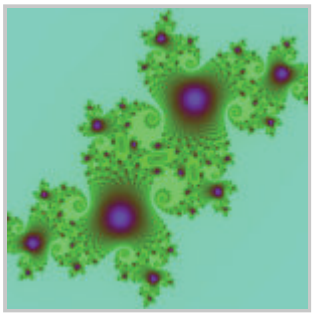
Mandelbrot, B. *Fractals: Form, Chance and Dimension*, W. H. Freeman and Company, 1977, xviii + 265 pp.

Mandelbrot, B. *The Fractal Geometry of Nature*, W. H. Freeman and Company, 1982, xii + 461 + xvi pp. (twenty-two reprints by 2005)

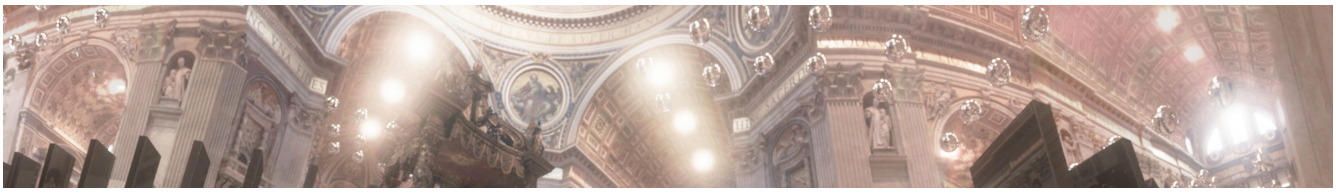
Mandelbrot, B. *Fractals and Chaos: The Mandelbrot Set and Beyond*, New York NY: Springer, 2004, xii + 308 pp.

Lane, J., L. Carpenter, T. Whitted, and J. Blinn, "*Scan Line Methods for Displaying Parametrically Defined Surfaces*," CACM, 23(1), January 1980.

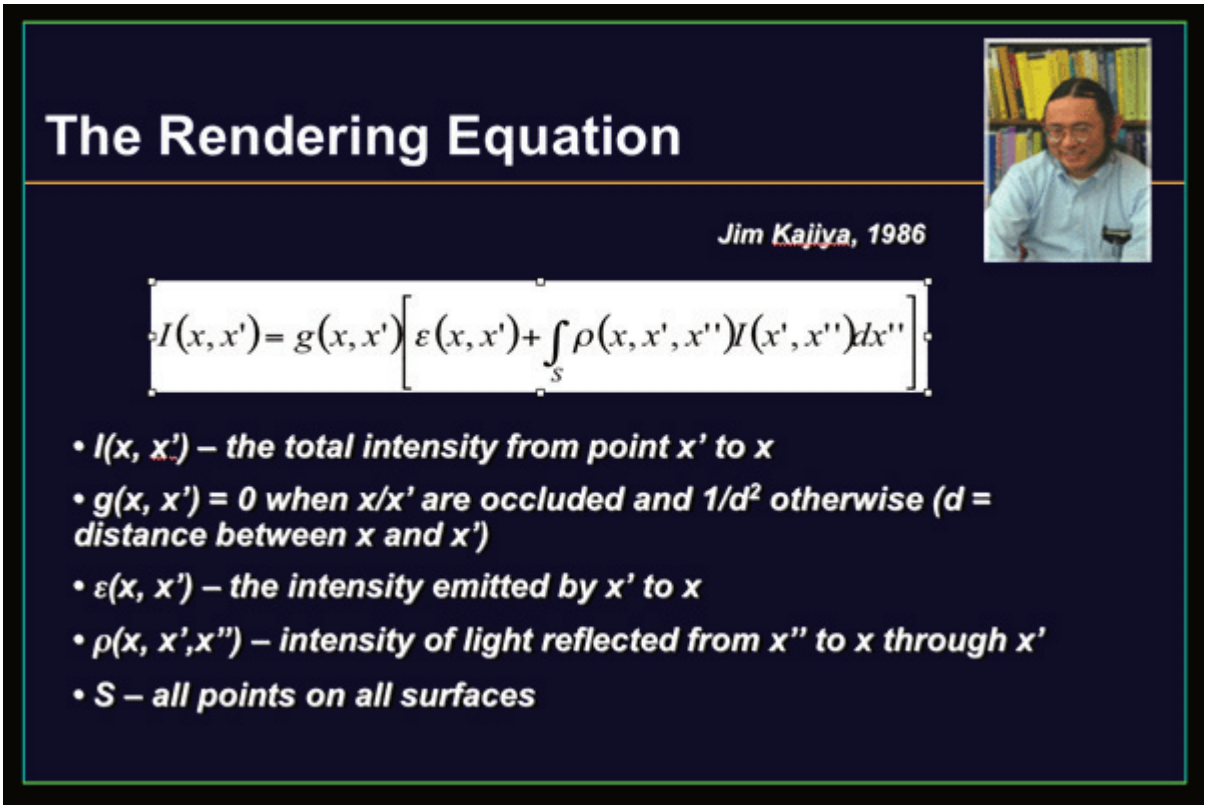
Gallery 19.3 Fractal Images

19.5 Global Illumination



Another important component of complex and realistic images is accurate lighting. Lighting is one of the most complicated of all computer graphics algorithms, and it is also one of the most critical for believable images. The lighting is what gives the surface detail that is keyed to the object's physical properties. The basis of most lighting approximation techniques is in estimating the amount of light energy being transmitted, reflected or absorbed at a given point on a surface. Almost every reasonable algorithm is derived from the **rendering equation**, a very important contribution to the field of computer graphics by **James T. Kajiya** of CalTech in 1986. Kajiya based his idea on the theory of radiative heat transfer.



The intensity of light that travels from point x' to point x assumes there are no surfaces between to deflect or scatter the light.
I(x, x') is that energy of radiation per unit time per unit area of source dx' per unit area dx of the target. In many cases, computer graphics researchers do not deal with joules of energy when talking about intensity of light. Instead, more descriptive terms are used. White, for example, is considered a hot (or high intensity) color while deep blues, purples and very dark shades of grey are cool (or low intensity) colors. Once all calculations are done, the numerical value of I(x, x') is usually normalized to the range [0.0, 1.0].

The quantity g(x, x') represents the occlusion between point x' and point x. The value of g(x, x') is exactly zero if there is no straight line-of-sight from x' to x and vice versa. From a geometric standpoint this makes perfect sense. If the geometry of the scene is such that no light can travel between two points, then whatever illumination that x' provides cannot be absorbed and/or reflected at x. If there is, however, some mutual visibility between the two points, g(x, x') is equal to the inverse of r squared where r is the distance from x' to x (a common physics law).

The amount of energy emitted by a surface at point x' reaching a point x is measured in per unit time per unit area of source per unit area of target. This sounds very similar for the units of transport intensity I. The difference however, is that emittance is also a function of the distance between x' and x.

Surfaces are often illuminated indirectly. That is, some point x receives scattered light from point x' that originated from x". The scattering term is a dimensionless quantity.

As one can conclude from the equation itself, evaluating the integrated intensity I for each point on a surface is a very expensive task. Kajiya, in the paper that introduced the rendering equation, also introduced a **Monte**

Carlo method for approximating the equation. Other good approximations have since been introduced and are widely used, but the theory introduced by Kajiya has influenced the derivation of most alternative approaches. Also, much simplified equations for I(x, x') are typically substituted in the case of indoor lighting models.

Global illumination refers to a class of algorithms used in 3D computer graphics which, when determining the light falling on a surface, takes into account not only the light which has taken a path directly from a light source (local illumination), but also light which has undergone reflection from other surfaces in the world. This is the situation for most physical scenes that a graphics artist would be interested in simulating.

Images rendered using global illumination algorithms are often considered to be more photorealistic than images rendered using local illumination algorithms. However, they are also much slower and more computationally expensive to create as well. A common approach is to compute the global illumination of a scene and store that information along with the geometry. That stored data can then be used to generate images from different viewpoints within the scene (assuming no lights have been added or deleted). Radiosity, ray tracing, cone tracing and photon mapping are examples of global illumination algorithms.

Radiosity was introduced in 1984 by researchers at Cornell University (Goral, etal) in their paper *Modeling the interaction of light between diffuse surfaces*. Like Kajiya's rendering equation, the radiosity method has its basis in the theory of thermal radiation, since radiosity relies on computing the amount of light energy transferred between two surfaces. In order to simplify the algorithm, the radiosity algorithm assumes that this amount is constant across the surfaces (perfect or ideal **Lambertian** surfaces); this means that to compute an accurate image, geometry in the scene description must be broken down into smaller areas, or patches, which can then be recombined for the final image.



Form factors used by radiosity algorithm

The amount of light energy transfer can be computed by using the known reflectivity of the reflecting patch and the emission quantity of an "illuminating" patch, combined with what is called the **form factor** of the two patches. This dimensionless quantity is computed from the geometric orientation of the two patches, and can be thought of as the fraction of the total possible emitting area of the first patch which is covered by the second patch.

The form factor can be calculated in a number of ways. Early methods used a hemicube (an imaginary cube centered upon the first surface to which the second surface was projected, devised by Cohen and Greenberg in 1985) to approximate the form factor, which also solved the intervening patch problem. This is quite computationally expensive, because ideally form factors must be derived for every possible pair of patches, leading to a quadratic increase in computation with added geometry.

Ray tracing is one of the most popular methods used in 3D computer graphics to render an image. It works by tracing the path taken by a ray of light through the scene, and calculating reflection, refraction, or absorption of the ray whenever it intersects an object (or the background) in the scene.

For example, starting at a light source, trace a ray of light to a surface, which is transparent but refracts the light beam in a different direction while absorbing some of the spectrum (and altering the color). From this point, the beam is traced until it strikes another surface, which is not transparent. In this case the light undergoes both absorption (further changing the color) and reflection (changing the direction). Finally, from this second surface it is traced directly into the virtual camera, where its resulting color contributes to the final rendered image.

Ray tracing's popularity stems from its realism over other rendering methods; effects such as reflections and shadows, which are difficult to simulate in other algorithms, follow naturally from the ray tracing algorithm. The main drawback of ray tracing is that it can be an extremely slow process, due mainly to the large numbers of light rays which need to be traced, and the larger number of potentially complicated intersection calculations between light rays and geometry (the result of which may lead to the creation of new rays). Since very few of the potential rays of light emitted from light sources might end up reaching the camera, a common optimization is to trace hypothetical rays of light in the opposite direction. That is, a ray of light is traced starting from the camera into the scene, and back through interactions with geometry, to see if it ends up back at a light source. This is usually referred to as backwards ray tracing.

Nonetheless, since its first use as a graphics technique by Turner Whitted in 1980, much research has been done on acceleration schemes for ray tracing; many of these focus on speeding up the determination of whether a light ray has intersected an arbitrary piece of geometry in the scene, often by storing the geometric database in a spatially organized data structure. Ray tracing has also shown itself to be very versatile, and in the last decade ray tracing has been extended to global illumination rendering methods such as photon mapping and Metropolis light transport.

Photon mapping is a ray tracing technique used to realistically simulate the interaction of light with different objects. It was pioneered by Henrik Wann Jensen. Specifically, it is capable of simulating the refraction of light through a transparent substance, such as glass or water, diffuse inter-reflections between illuminated objects, and some of the effects caused by particulate matter such as smoke or water vapor.

In the context of the refraction of light through a transparent medium, the desired effects are called caustics. A caustic is a pattern of light that is focused on a surface after having had the original path of light rays bent by an intermediate surface.

With photon mapping (most often used in conjunction with ray tracing) light packets (photons) are sent out into the scene from the light source (reverse ray tracing) and whenever they intersect with a surface, the 3D coordinate of the intersection is stored in a cache (also called the photon map) along with the incoming direction and the energy of the photon. As each photon is bounced or refracted by intermediate surfaces, the energy gets absorbed until no more is left. We can then stop tracing the path of the photon. Often we stop tracing the path after a pre-defined number of bounces, in order to save time.

Also to save time, the direction of the outgoing rays is often constrained. Instead of simply sending out photons in random directions (a waste of time), we send them in the direction of a known object that we wish to use as a photon-manipulator to either focus or diffuse the light.

This is generally a pre-process and is carried out before the main rendering of the image. Often the photon map is stored for later use. Once the actual rendering is started, every intersection of an object by a ray is tested to see

if it is within a certain range of one or more stored photons and if so, the energy of the photons is added to the energy calculated using a more common equation.

There are many refinements that can be made to the algorithm, like deciding where to send the photons, how many to send and in what pattern. This method can result in extremely realistic images if implemented correctly.



Paul Debevec

Paul Debevec earned degrees in Math and Computer Engineering at the University of Michigan in 1992 and a Ph.D. in Computer Science at UC Berkeley in 1996 [1]. He began working in image-based rendering in 1991 by deriving a textured 3D model of a Chevette from photographs for an animation project. At Interval Research Corporation he contributed to Michael Naimark's Immersion '94 virtual exploration of the Banff National forest and collaborated with Golan Levin on Rouen Revisited, an interactive visualization of the Rouen Cathedral and Monet's related series of paintings. Debevec's Ph.D. thesis presented an interactive method for modeling architectural scenes from photographs and rendering these scenes using **projective texture-mapping**. With this he led the creation of a photorealistic model of the Berkeley campus for his 1997 film *The Campanile Movie* whose techniques were later used to create the virtual backgrounds for the "bullet time" shots in the 1999 Keanu Reeves film *The Matrix*.



Scene from Fiat Lux

Since his Ph.D. Debevec has worked on techniques for capturing real-world illumination and illuminating synthetic objects with real light, facilitating the realistic integration of real and computer generated imagery. His 1999 film *Fiat Lux* placed towering monoliths and gleaming spheres into a photorealistic reconstruction of St. Peter's Basilica, all illuminated by the light that was actually there. For real objects, Debevec led the development of the Light Stage, a device that allows objects and actors to be synthetically illuminated with any form of lighting. In May 2000 Debevec became the Executive Producer of Graphics Research at USC's Institute for Creative Technologies, where he directs research in virtual actors, virtual environments, and applying computer graphics to creative projects.



Image-based lighting

1. from Paul Debevec's bio at http://www.debevec.org/



Rendering with Natural Light

In 2001 Paul Debevec received ACM SIGGRAPH's first Significant New Researcher Award for his Creative and Innovative Work in the Field of Image-Based Modeling and Rendering, and in 2002 was named one of the world's top 100 young innovators by MIT's Technology Review Magazine.

Movie 19.13 Fiat Lux – The Movie



http://www.pauldebevec.com/FiatLux/movie/
Produced in 1999 by Paul Debevec showing elaborate lighting techniques

Kajiya, Jim, The Rendering Equation, Computer Graphics, 20(4):143-150, Aug. 1986.

Cindy Goral, Ken Torrance, Don Greenberg and B. Battaile, *Modeling the interaction of light between diffuse surfaces*. Computer Graphics, V18, #3, July 1984.

Paul Debevec is the consummate researcher and is very prolific in publishing and filmmaking. An extended list of his research, projects and films is at

http://www.pauldebevec.com
His publication list can be found at
http://ict.debevec.org/~debevec/Publications/

Movie 19.14 Campanile
http://www.youtube.com/watch?v=RPhGEiM_6lM

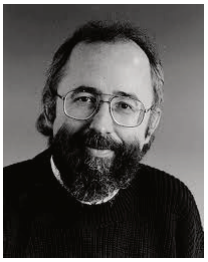
Movie 19.15 Rendering with Natural Light (Radeon implementation)
http://www.youtube.com/watch?v=fW_GPCR9_GU

Movie 19.16 Simulation of the Parthenon Lighting
http://www.youtube.com/watch?v=QeWLpTLzZVc

Movie 19.17 Presentation by Paul Debevec
Achieving Photo-Real Digital Actors
Palo Alto Film Festival
http://www.youtube.com/watch?v=VKx_DZp_0EI

19.6 Plants





Przemyslaw Prusinkiewicz

Dr. Przemyslaw Prusinkiewicz's interest in computer graphics began in the late 1970s. By 1986 he originated a method for visualizing the structure and growth of plants based on **L-systems**, a mathematical theory of development of multicellular organisms introduced by the late Professor Aristid Lindenmayer. Prusinkiewicz, his students, and collaborators transformed L-systems into a powerful programming language for expressing plant models, and extended the range of phenomena that can be simulated. Specifically, parametric L-systems facilitate the construction of models by assigning attributes to their components. Differential L-systems make it possible to simulate plant growth in continuous time, which is essential to the animation of developmental processes. Environmentally-sensitive and open L-systems provide a framework for simulating the interactions between plants and their environment. The power of these concepts is demonstrated by the wide range of biological structures already modeled, from algae to wild flowers to gardens and stands of trees competing for light.

In addition to the important extensions of L-systems, Prusinkiewicz's research also includes studies of fundamental problems of morphogenesis – emergence of patterns and three dimensional forms in nature. This includes the modeling of spiral phyllotactic patterns in plants, and developmental patterns and forms of seashells.

As a result of the research on the extension of L-systems, plants can be modeled with unprecedented visual and behavioral fidelity to nature. Prusinkiewicz authored the book, *The Algorithmic Beauty of Plants*, demonstrating that plant models can be combined artistically into stunning and inspiring images. His website, Visual Models of Morphogenesis: A Guided Tour is a spectacular explanation of the techniques used to model organic shapes such as plants.

The website for Prusinkiewicz' research lab at the University of Calgary can be found at

http://www.cpsc.ucalgary.ca/Research/bmv/vmm-deluxe/TableOfContents.html

John Hutchinson demonstrated in 1981 a branch of mathematics now known as *Iterated Function Theory*. Later in the decade Michael Barnsley, a leading researcher from Georgia Tech, wrote the popular book *Fractals Everywhere*. The book presented the mathematics of **Iterated Functions Systems** (IFS), and proved a result known as the Collage Theorem.

An IFS fractal, according to Barnsley, is defined by a set of elementary geometric transformations which are called "linear" or "**affine**" by mathematicians. In the everyday language, they are a combination of

- translations
- rotations
- linear compressions along the vertical or horizontal axis, or both. The compression ratios along the two axes can be different.
- vertical or horizontal shears, such that a rectangle is transformed into a parallelogram through the sliding of a side along itself.

The only requirement is that the transformations must be contractive, i.e. the distance between two points must decrease (at least, not increase) in the transformation.The transformations to be implemented in the IFS set depend upon the figure to be redrawn. As Barnsley stated, "There is a magical precept that must be satisfied: if the target figure is transformed through the various transformations in the set, one must get exact parts of this figure, and superimposing all these parts must reconstruct the whole figure."



Barnsley introduced the theory of Iterated function systems (IFS): with a small set of affine transformations it is possible to generate every type of self-similar fractals. Based on IFS, Barnsley has a patent for an algorithm that compresses every picture to FIF: fractal image format.

The Collage Theorem presented a possibility that intrigued researchers, particularly Barnsley and some of his students. If, in the forward direction, fractal mathematics is good for generating natural looking images, then, in the reverse direction, could it not serve to compress images? Going from a given image to an Iterated Function System that can generate the original (or at least closely resemble it), is known as the inverse problem.

Barnsley and his research team applied the Collage Theorem to try and solve the inverse problem, and published the technique in articles for Computer Graphics World and a famous article in the January 1988 Byte Magazine issue. He and Alan Sloan applied for and were granted a software patent, and left Georgia Tech to found Iterated Systems Inc. This Byte article didn't really address the inverse problem directly, but it did exhibit several images purportedly compressed in excess of 10,000:1.

The images were given suggestive names such as "Black Forest" and "Monterey Coast" and "Bolivian Girl" and they were all manually constructed.

M.F. Barnsley and S. Demko, *Iterated function systems and the global construction of fractals*, Proc. Roy. Soc. London A399, 243-275 (1985).

J. Hutchinson, *Fractals and self-similarity*, Indiana Univ. J. Math. 30, 713-747 (1981).

M.F. Barnsley, V. Ervin, D. Hardin and J. Lancaster, *Solution of an inverse problem for fractals and other sets*, Proc. Nat. Acad. Sci. USA 83, 1975-1977 (1985).

Barnsley, M.F., *Fractals Everywhere*, Academic press, 1988

Barnsley, M.F., and Sloan, A.D., *A Better Way to Compress Images*, Byte Magazine, January 1988, Pages 215-222

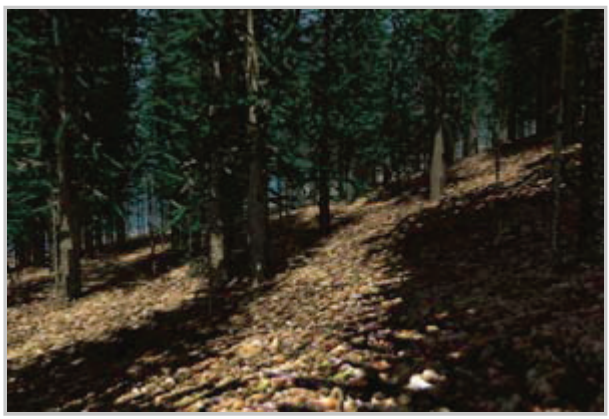
Barnsley and Sloan, *Chaotic Compression*, Computer Graphics World, November 1987. Pennwell Publishing

Midori Kitagawa, an associate professor in the Department of Art and the Advanced Computing Center for the Arts and Design at Ohio State, developed the Branching Object Generation and Animation System (BOGAS) [1] to create realistic models of trees, plants, blood vessels, nervous systems, underwater animals and even imaginary

1. Kitagawa developed the Branching Object Generation and Animation System (BOGAS) which generated and animated branching structures, such as trees and plants. It was used in visualization research and art making.

creatures. The system was designed to help scientists, botanists and artists visualize realistic branching objects, permitting them to generate the objects interactively and then to see how factors like gravity and sunlight affect growth.





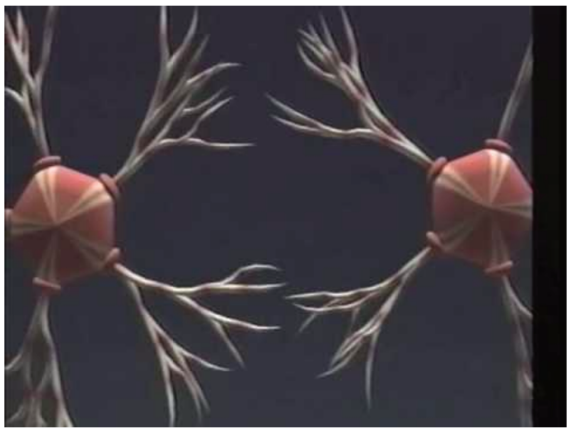


Scene from I Have Never Seen, But I Know…



Scene from I Have Never Seen, But I Know…

Movie 19.18 I Have Never Seen, But I Know…



https://www.youtube.com/watch?v=Xb50LQ8lhAU

Film by Midori Kitagawa (1990) using the BOGAS system for plant generation. Music by Daniel Remler (Ohio State University ACCAD)

Kitagawa De Leon, M. *Branching Object Generation and Animation System with Cubic Hermite Interpolation*, Journal of Visualization and Computer Animation. 2, 2, 60-67, 1994.

Images in the gallery below, in order are:

Developmental sequence of Mycelis muralis.
Copyright © 1987 P. Prusinkiewicz and J. Hanan.

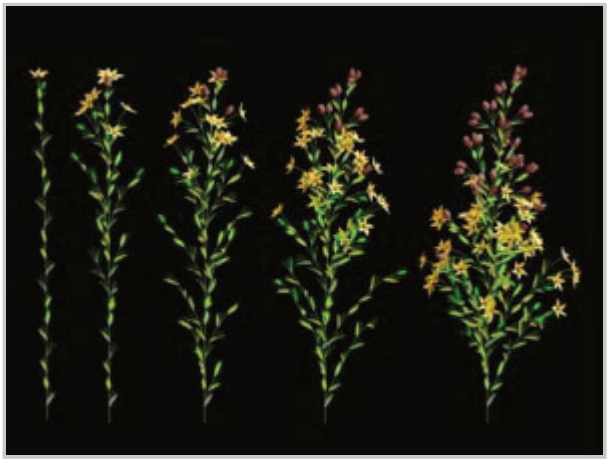
The Garden of L.
Copyright © 1988 P. Prusinkiewicz, F.D. Fracchia, J. Hanan, and D. Fowler.

Green coneflower.
Copyright © 1992 D. Fowler, P. Prusinkiewicz, and J. Battjes.

Table of cacti, including realistic models of the elongated Mammillaria spinosissima.
Copyright © 1992 D. Fowler, P. Prusinkiewicz, and J. Battjes.

Topiary dinosaur.
R. Mech, P. Prusinkiewicz, and B. Wyvill.
Copyright © 1994 P. Prusinkiewicz.

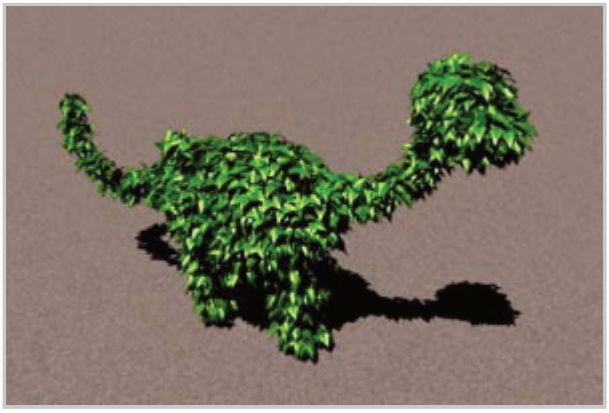
Gallery 19.4 Images from Prusinkiewicz



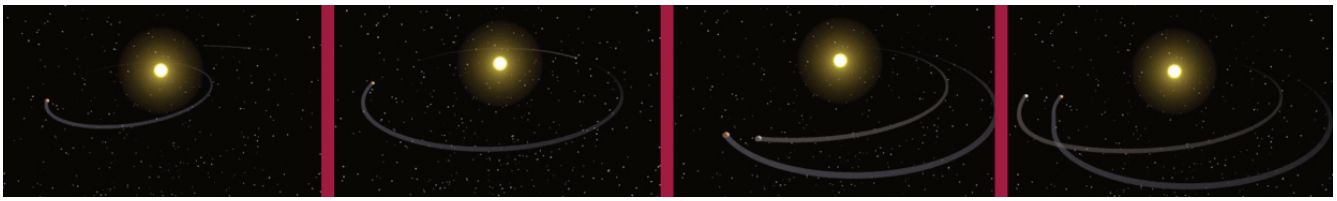








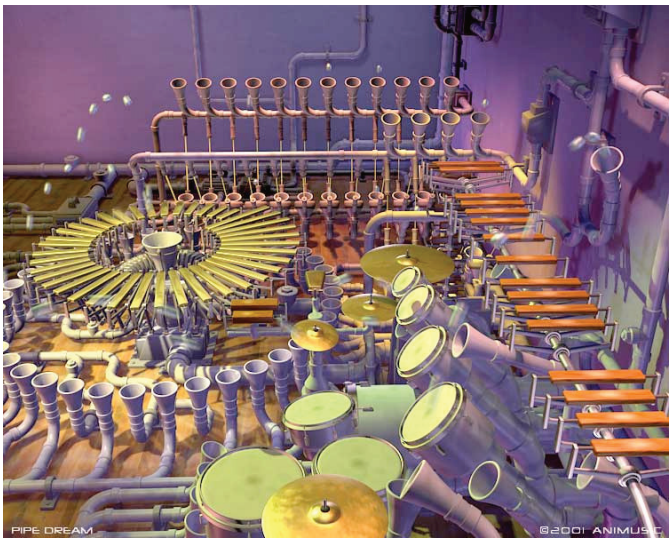
19.7 Data-driven Imagery



Wayne Lytle began his graphics career as a visualization staff member at the Cornell Theory Center. He received a Master's degree from Cornell in 1989 with his thesis titled "*A modular testbed for realistic image synthesis*". His first full multi-instrument music animation *More Bells and Whistles* premiered in the Electronic Theater at SIGGRAPH 1990. It has since won awards and been shown in various contexts world-wide. In 1991 Lytle received an award from IBM for his early work in music animation. Lytle also contributed to the debate about standards for visual representation, which persists along with questions about numerical simulations. This was illustrated by an animation from the Cornell Theory Center by Lytle called *The Dangers of Glitziness and Other Visualization Faux Pas*, using fictitious software named *Viz-o-Matic*. The video, shown in the Electronic Theater at SIGGRAPH 93, documented the enhancement and subsequent "glitz buffer overload" of a sparsely data-driven visualization trying to masquerade as a **data-driven**, thoughtfully rendered presentation.



Scene from More Bells and Whistles



Scene from Pipe Dreams

In 1995, Lytle formed Animusic, a content creation company. Two of the more famous animations are *Stick Figures* and *Pipe Dreams*, shown at SIGGRAPH 2000 and 2001, respectively. The principle focus of Animusic is the production of 3D computer graphics music animation. Animusic uses proprietary motion generation software called MIDImotion™. Without this software, animating instruments using traditional "keyframing" techniques would be prohibitively time-consuming, and inaccurate. By combining motion generated by approximately 12 algorithms (each with 10 to 50 parameters), the instrument animation is automatically generated with sub-frame accuracy. If the music is changed, the animation is regenerated effortlessly.

The technique differs significantly from reactive sound visualization technology, as made popular by music player plug-ins. Rather than reacting to sound with undulating shapes, the animation is correlated to the music at a note-for-note granularity, based on a non-real-time analysis pre-process. Animusic instruments generally appear to generate the music heard, rather than respond to it.



Scene from Scene from Stick Figures

At any given instant, not only do they take into account the notes currently being played, but also notes recently played and those coming up soon. These factors are combined to derive "intelligent", natural-moving, self-playing instruments. And although the original instruments created for the"video album" are reminiscent of real instruments, the motion algorithms can be applied to arbitrary graphics models, including non-instrumental objects and abstract shapes.

Movie 19.19 More Bells and Whistles
http://www.youtube.com/watch?v=qSdR4gFumps

Movie 19.20 Stick Figures
https://www.youtube.com/watch?v=LM6kB6ce_5M
Movie 19.21 Pipe Dreams

https://www.youtube.com/watch?v=Xu-A0jqMPd8

The Dangers of Glitziness and Other Visualization Faux Pas

Steve May, **Kirk Bowers**, and **Mark Fontana** produced in 1997 an animation titled *Butterflies in the Rain*, which tells the story of a butterfly exploring a piano that is mysteriously being played by water droplets falling from above. The piece is accompanied by and algorithmically synchronized to MIDI music data transcribed from the reproducing piano roll *Butterflies in the Rain*, a piece from the 1930's composed by Sherman Myers and played by Frank Milne.



Scenes from "Butterflies in the Rain"

The animation makes extensive use of procedural techniques. All modeling and animation was done using AL, an animation system developed by Steve May. PhotoRealistic RenderMan ® (Pixar) was used for rendering. Houdini (Side Effects) was used for compositing. All work was performed on Silicon Graphics workstations.

Movie 19.22 Butterflies in the Rain



https://www.youtube.com/watch?v=lVXmtckavDQ

Based on a concept by Brad Winemiller, this film was produced by Kirk Bowers, Mark Fontana and Steve May at The Ohio State University's Advanced Computing Center for the Arts and Design (ACCAD). Additional modeling support (piano harp and strings) was provided by Phil Massimi. Software used was emacs (text editor) for modeling, Steve May's Scheme-based Animation Language ("AL") for animation, GIMP for texture maps, Pixar's RenderMan for rendering, and Side Effects' Houdini for compositing.

19.8 Character motion





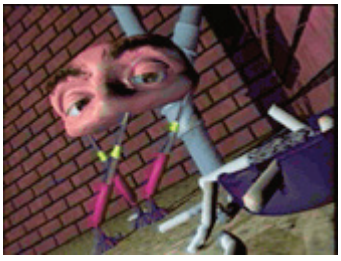
Chris Landreth

After graduating from the University of Illinois with a specialty in mechanical engineering, **Chris Landreth** joined the North Carolina Supercomputing Center as a scientific visualization animator. He later became a Senior Animator at NCSC, where he produced his famous animation *Data Driven: The Story of Franz K.* (1993) in which various artistic elements were mixed with scientific visualization procedures to create a compelling animation.



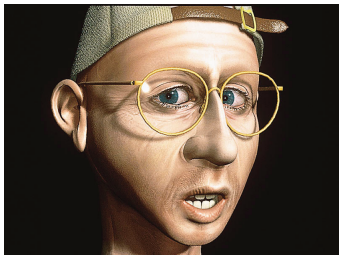
Scene from Date Driven: The Story of Franz K.

In 1994, he went to Alias/Wavefront as a Senior Animator, where he produced *the end* (which won a number of awards in addition to an Academy Award nomination.) He has become known for his advanced character animations and scientific visualizations which explore unique ways of representing humanity and nature.



Scene from The Listener

Other Landreth works include *The Listener* (1991), *Caustic Sky: A Portrait of Regional Acid Deposition* (1992), and *Bingo* (1998). *Bingo* is based on the short play *Disregard This Play* by Chicago's Neo-Futurist Theatre Company. The story deals with the age-old question: "What if a lie is told long enough and loud enough?" *Bingo* is the first animated short fully produced with Alias/Wavefront's animation software, Maya.



Scene from Bingo



Scene from Bingo

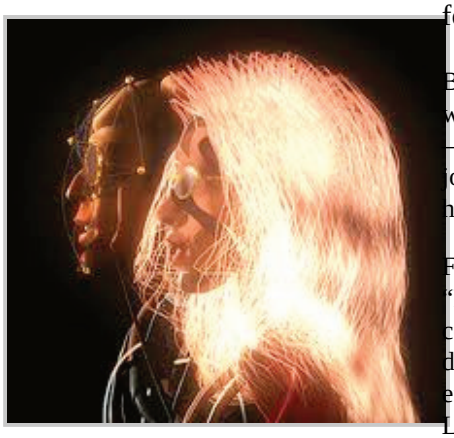
Bingo was originally conceived as an extensive in-house quality assurance project aimed at rigorously testing and demonstrating the technical capabilities of Maya. In Landreth's words, "This was in many ways a very unusual production. We were an ad-hoc production studio within a software development company. During this production, people who were programmers, testers and expert users became some of the most brilliant modelers, animators, technical directors and rendering artists I've ever seen in a production environment."



Ryan



The following text is by Amy Johns from the October, 1998 Wired Magazine:

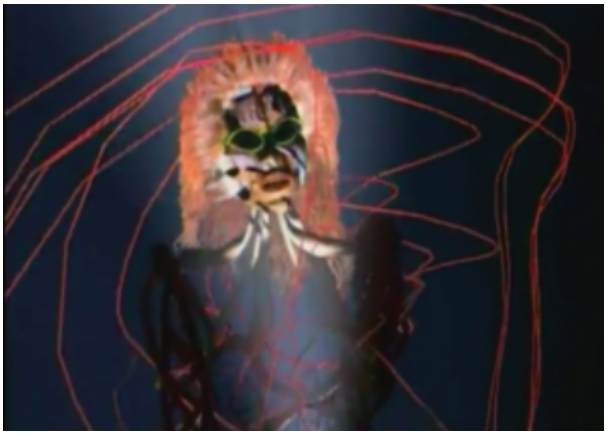


Beta testers don't usually get much attention on Oscar night. But Chris Landreth – who was nominated for an Academy Award for his 1996 all-digital short *The End* – is not your usual guy. A senior animator at Alias|Wavefront, Landreth says his job is "to be a tyrant." Long before his company's Maya program hit top f/x houses, Landreth put it to the test, searching for bugs and demanding new features.

For this untrained artist and onetime mechanical engineer, working at Alias is a "Faustian deal." He pushes, prods, and tests products, and in exchange he gets company time to create his own animations. His latest tour de force, Bingo, is a disturbing short based on a play by Chicago's Neo-Futurists. The eerily lifelike effects – from the swing of a pigtail to the twitch of an eyebrow – exploit features Landreth wrested from coders during a year and a half of testing.

In the increasingly specialized CG industry, Landreth relishes his dual role: "I am able to be technical – to help design the software – and at the same time be an artist who tells a story with those tools."

Movie 19.23 *the end* – Chris Landreth



https://vimeo.com/23454509.
"the end" was a short film produced by animator Chris Landreth to demonstrate the capabilities of the Alias/ Wavefront suite of software modules. It was nominated for an Academy Award in 1996

Movie 19.24 *Bingo* – Chris Landreth



https://vimeo.com/23191218
Created in 1998, this film was produced by animator Chris Landreth as part of the development of the Maya animation system.

Scientific Visualization article by Landreth and Rheingold
http://www.cs.umbc.edu/~rheingan/pubs/perception.html

"*Hair-Raising Effects*"
Barbara Robertson, CGW October 1995 (hair simulation)

"*Read My Lips*"
Barbara Robertson, CGW August 1997 (lip-synch)

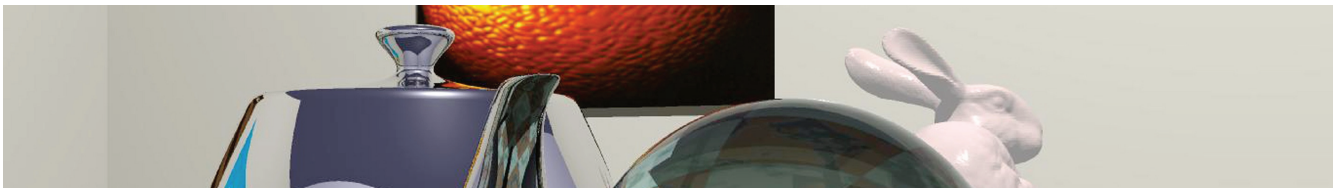
Chapter 20: CG Icons

CG Icons

Computer Graphics researchers and animators commonly used 3D objects for algorithm and system testing. The more they were used, the more iconic they became.



20.1 CG Icons



The Teapot

The Utah teapot is a 3D model which has become a standard reference object in the computer graphics community. It is a simple, round, partially concave mathematical model of an ordinary teapot.

The teapot data was created in 1975 by early computer graphics researcher Martin Newell, a member of the pioneering graphics program at the University of Utah. Newell needed a moderately simple mathematical model of a familiar object for his work, and his wife's teapot (a Melitta) provided a convenient solution. The shape contains a number of elements that make it ideal for the graphics experiments of the time – it's round, contains saddle-points, has a concave element (the hole in the handle), and looks reasonable when displayed without a complex surface texture.



Utah Teapot c. 1974

Newell made the mathematical data which describes the teapot's geometry (largely a set of three-dimensional coordinates) publicly available, and soon other researchers began to use the same data for their computer graphics experiments. These researchers needed something with roughly the same characteristics that Newell had, and using the teapot data meant they didn't have to laboriously enter geometric data for some other object. Although technical progress meant that the simple act of rendering the teapot was no longer the challenge it was in 1975, the teapot continued to be used as a reference object for increasingly advanced graphics techniques. The common (rather squat) appearance of the teapot differs from the

Melita original, reportedly because Newell's colleague Jim Blinn transformed it to compensate for the non-square pixels on his early frame buffer.

As the most common of the graphics icons, it was featured at the SIGGRAPH 89 conference in a "Call for Teapots" as part of the "Call for Participation".

> Originally purchased by graduate student Martin Newell in a Salt Lake City, Utah, department store, this ordinary teapot became a famous model used by many pioneers of the computer graphics community. Researchers developing rendering algorithms for texture and shading tested them on the data that described the teapot's shape. The actual teapot is about 30% taller than many of its computer-generated images because the data was originally recorded for the rectangular pixels of early displays.



Scene from cover of Conference Proceedings



Image from a video by Frank Crow to demonstrate capabilities of III software



Texture maps and reflection maps from Ed Catmull's dissertation









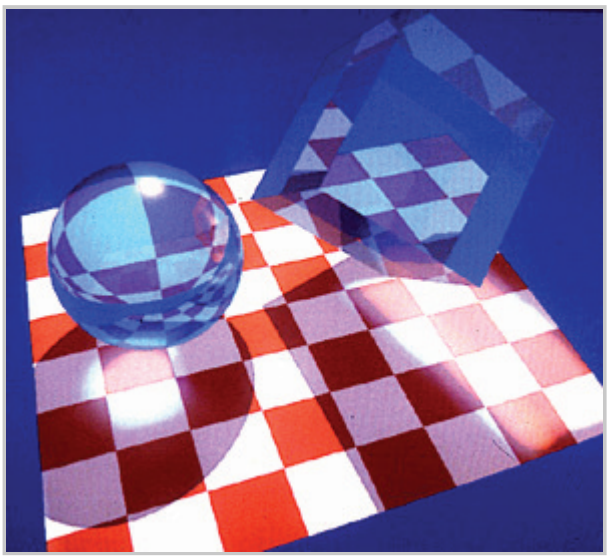
Ray-traced image by Arvo and Kirk – The Six Platonic Solids



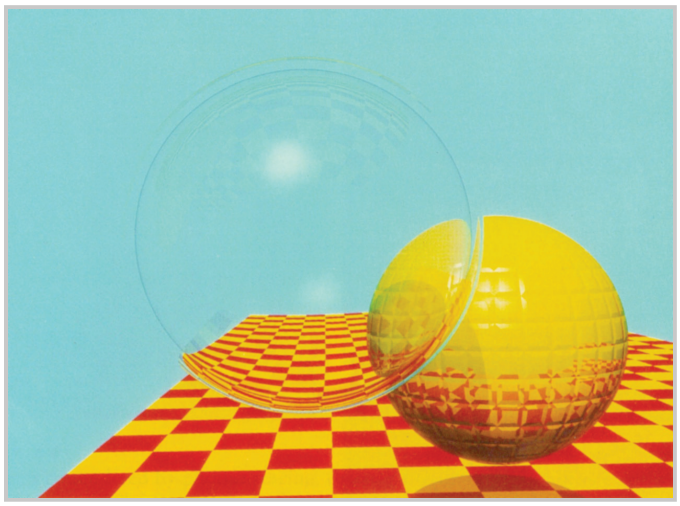
Pixar's Shutterbug series

Checkerboard floors and architectural columns

Two common elements of early computer generated images were the checkerboard floor plane and the column. The checkerboard was a good indicator of the perspective **foreshortening** effect, and also provided interesting visual effects in transparent and refractive surfaces. The column was an easy data set to create, usually being a regular surface of revolution. It provided a sense of depth and scale to the early images.



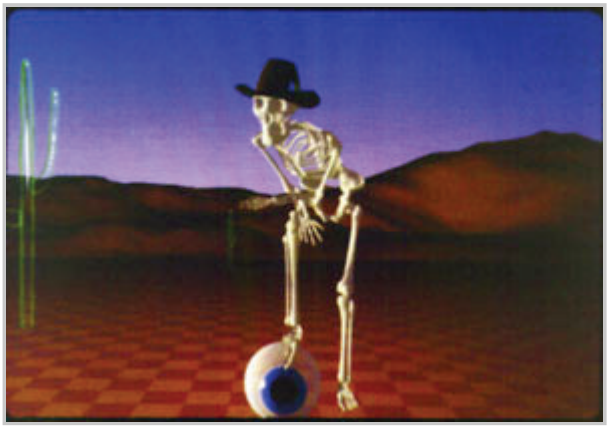
Turner Whitted – Bell Labs



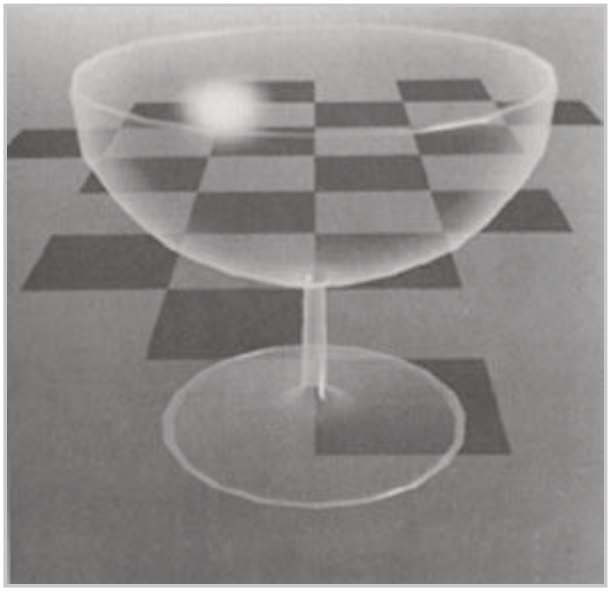
Turner Whitted – Bell Labs



“George in the Desert”



"George in the Desert" – data created by Don Stredney on DG2



Phong shading with transparency



Frank Crow



Wayne Carlson and Rick Balabuck -?Ohio State University



Ray-traced image by Arvo and Kirk – The Six Platonic Solids



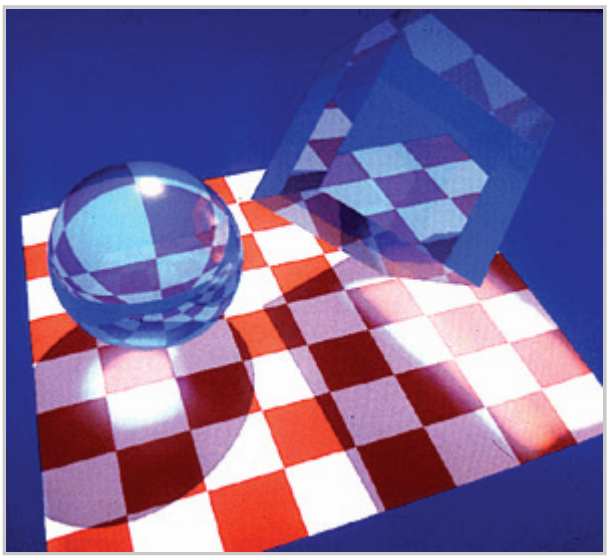
Arnold Gallardo, author of 3D Lighting: History, Concepts, and Techniques



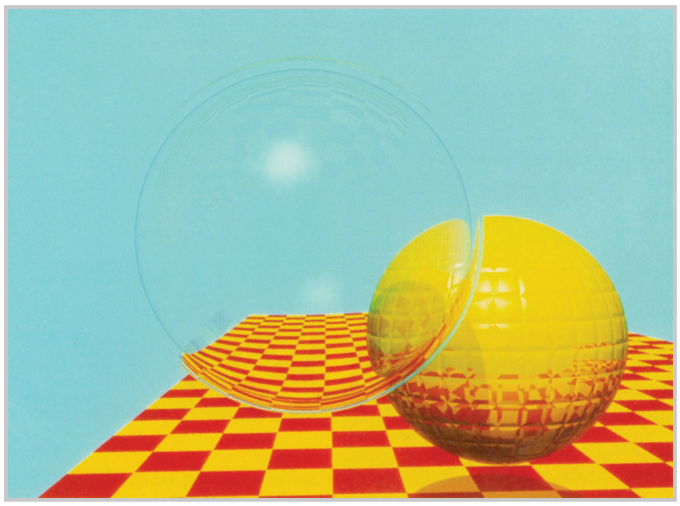
Eurhythmy

The ray-traced sphere

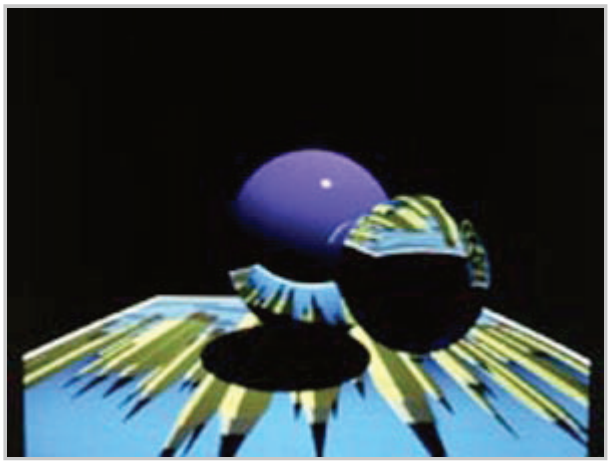
From the time that Turner Whitted demonstrated his now famous ray traced image, the sphere (solid, opaque, transparent, colored, etc.) has played a major role in the ray traced image. It is easy to create, it demonstrates nice effects with **refraction** and reflection, but most importantly the intersection computation between the cast rays and the spherical surface are relatively easy to compute in this otherwise compute intensive process.



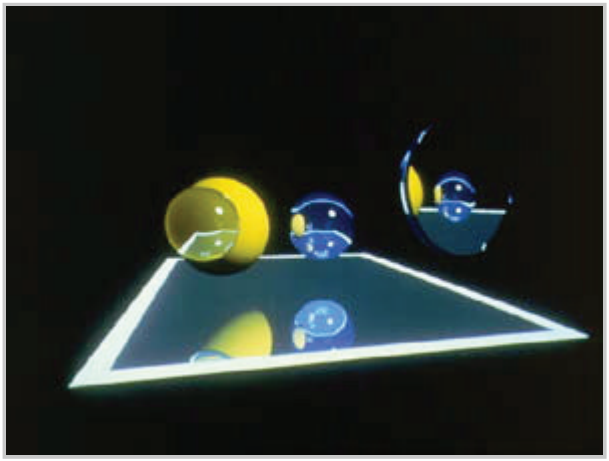
Turner Whitted – Bell Labs



Turner Whitted – Bell Labs



Hsuen Chung Ho – C/CP



Bob Conley – C/CP



Political Agenda
1999
Unix environment and AL
Cibachrome
122 x 165 cm (48 x 65 in.)

Collection of the Ohio
Supercomputer Center

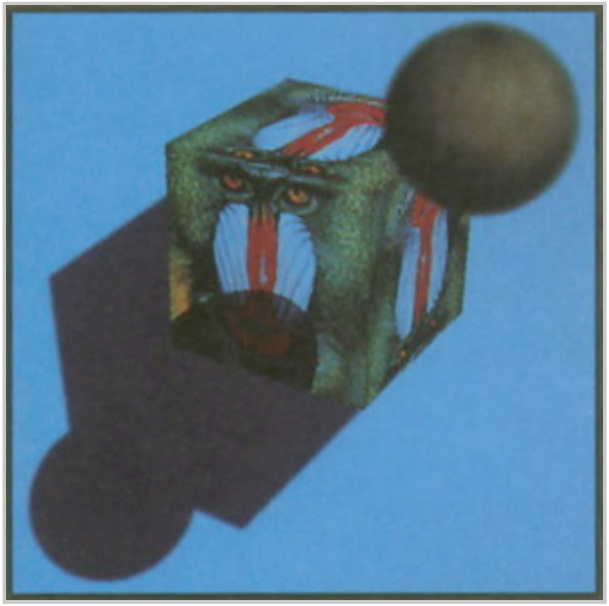
The Mandrill

Image processing and computer graphics have been linked for many years by many similar issues, theories and algorithms. They are also linked by the common usage of the image of the Mandrill, an ape with a distinctive colorful face. The image is very good for image compression, enhancement, an processing tests, and has been used very frequently as a texture map or background image for CGI purposes.



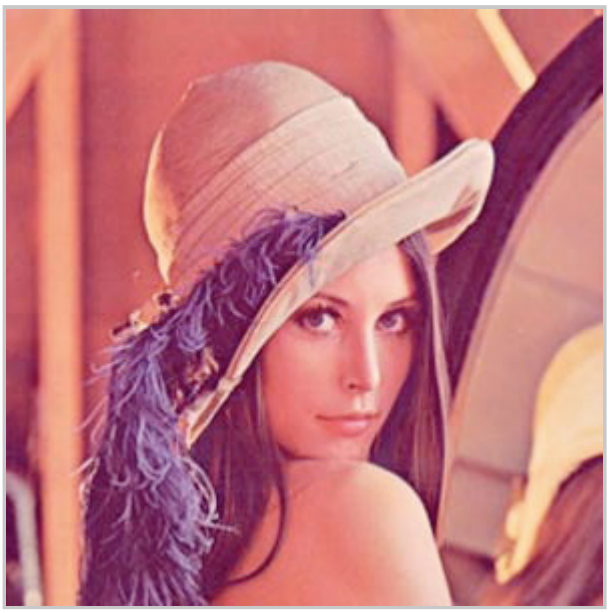


Indrinil Chakravarty and Michael Potmesil



Lena

The Lena image has been used for many years in graphics and for image processing tests. The original Lena image was a photograph of a Swedish woman named Lena Sjooblom, who originally was the *centerfold* in the November 1972 issue of Playboy Magazine. (In English, Lena is sometimes spelled Lenna, to encourage proper pronunciation.) The image was later digitized at the University of Southern California as one of many possible images for use by the imaging research community. The Lena image became a standard in the industry because the image contains a good mixture of detail, flat regions, shading, and texture that are important for testing various image processing algorithms.



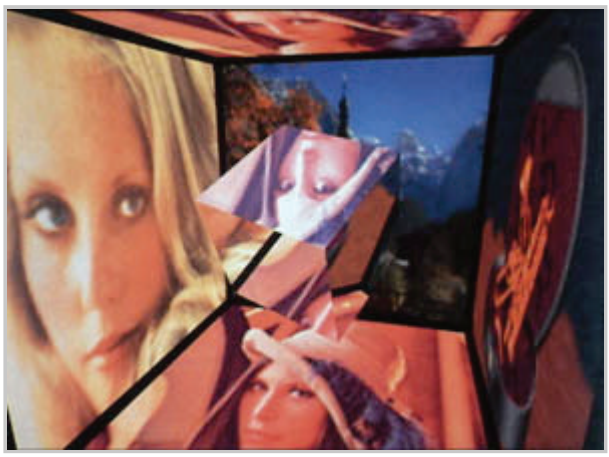
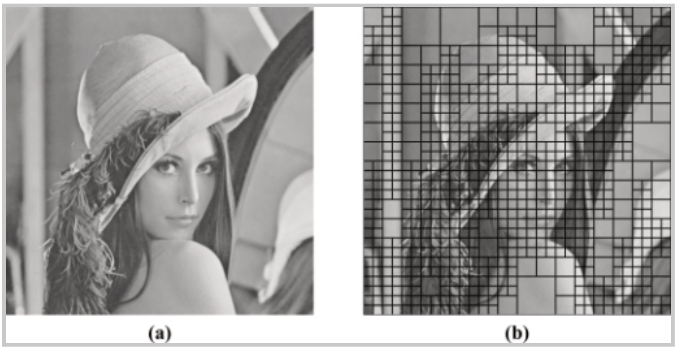


Image transformation



Quadtree decomposition



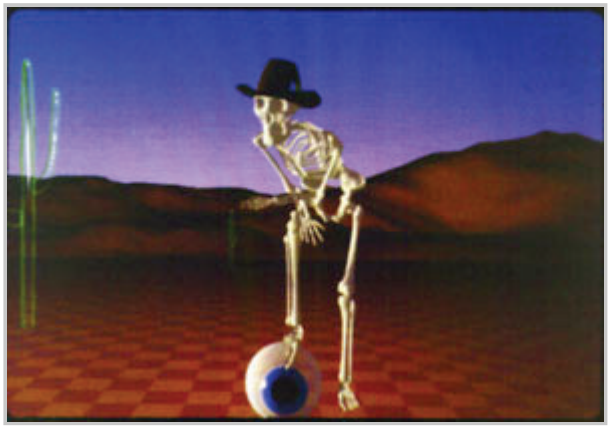
Edge detection

The skeleton

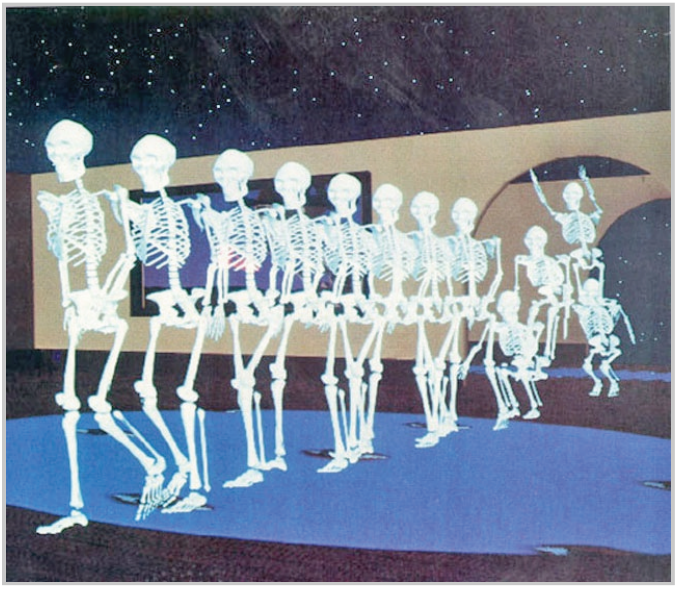
Because of the complexity of the structure of the human skeleton, it became a common model to demonstrate the capabilities of evolving 3D modeling systems. Animators, once they had the model, liked creating sequences in which the skeleton performed activities such as a real human form would participate in, such as dancing, singing, running, etc. This model, nicknamed "George" was created with Wayne Carlson's DG2 system at Ohio State by medical illustrator Don Stredney. It was placed in an ftp site, and was downloaded hundreds of times.



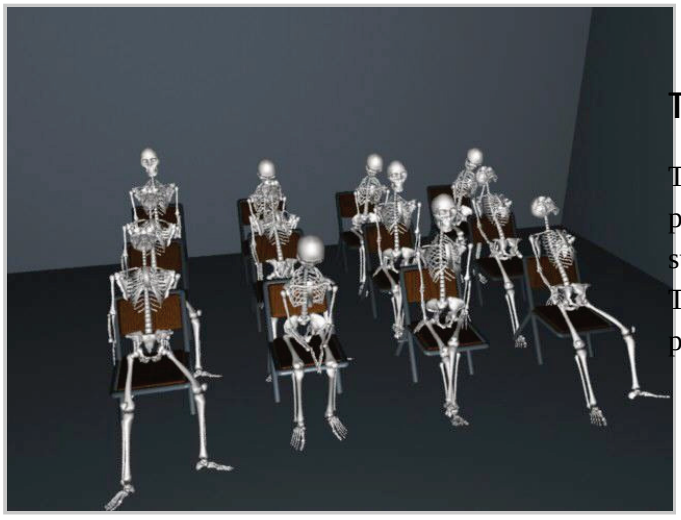
"George in the Desert"



"George in the Desert" – data created by Don Stredney on DG2



Scene composite from Zeltzer SAS system



Class time

The "donut"

The kind of geometry that the donut represents, the torus, provided challenges to early renderers and algorithms for such things as texture mapping because of the hole in it. Techniques were thus tested on the donut as a complex proof of concept.



Rob Rosenblum's Hairy Donots – Ohio State University



Jim Blinn's Bump Mapping



Perlin Noise Functions



Pixar's Shutterbug series

The VW bug

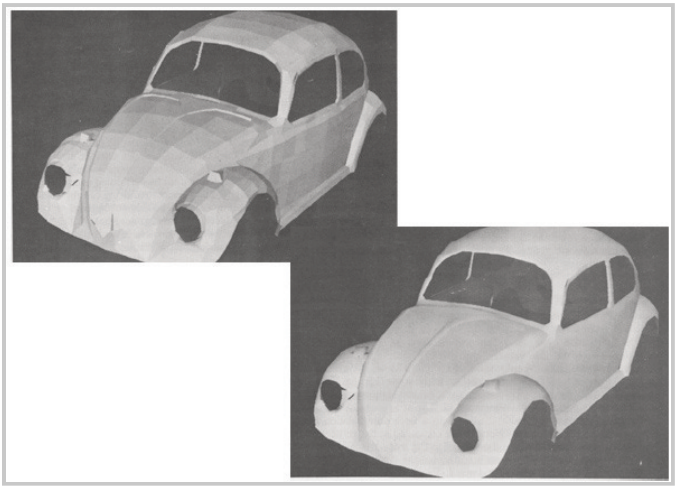
In order to get interesting data bases to use in the imaging experiments taking place at the University of Utah in the late 70s, Ivan Sutherland volunteered his Volkswagen bug to be digitized. Faculty and students taped off a grid of polygons and took measurements, resulting in a polygonal shell of a VW.



Digitizing Sutherland's Bug



University of Utah



Shading – University of Utah

The Stanford bunny

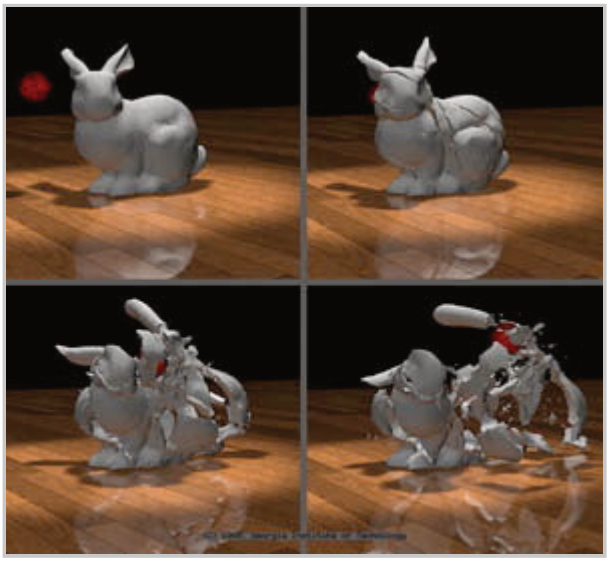
The Stanford Bunny model was originally constructed in 1994 by Greg Turk and Marc Levoy using a technique they developed to create polygonal models from range scans (Zippered Polygon Meshes from Range Images, Greg Turk and Marc Levoy, SIGGRAPH 94, pp. 311-318). The Bunny model consisted of 69,451 triangles. The model was created using a technique to create polygonal models from several range scans.

A range scan is a grid of distance values that tell how far the points on a physical object is from the device that creates the scans (usually known as a range scanner). One way to think of a range scan is as a 2D image of pixels, but in which each pixel contains a distance value instead of a color. In fact, one common way to examine a **range image** is to draw it as a black-and-white image, with shorter distances shown as bright pixels and farther distances being darker. It is usually necessary to piece together several range scans in order to capture the full geometry of an object. Because of the interesting geometry, researchers have used the bunny for everything from texture mapping tests, to
growing hair on it, to algorithmically breaking it into pieces.

The Bunny has it's own website at http://www.cc.gatech.edu/~turk/bunny/bunny.html.







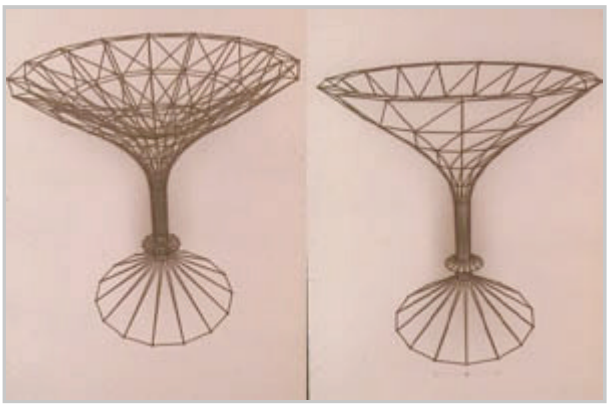
James O'Brien and Jessica Hodgins, Animating Fracture, CACM 7/2000



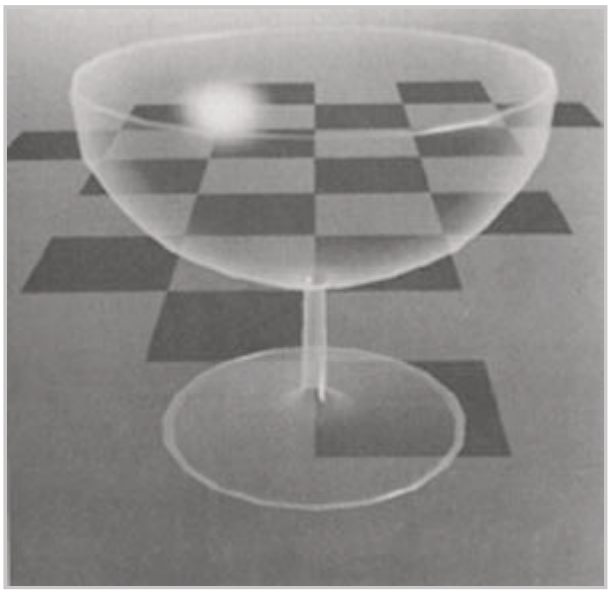
Range-scanned Bunny

The wineglass and vase

The wineglass and the vase were popular test models, because they were easy to generate the geometry (eg, a simple regular **surface of revolution**) and they had attributes that could demonstrate visible/hidden surfaces and rendering techniques, such as transparency, refractivity, **caustics**, etc.



Images from Jim Blinn, University of Utah



Phong shading with transparency



Jim Blinn, University of Utah

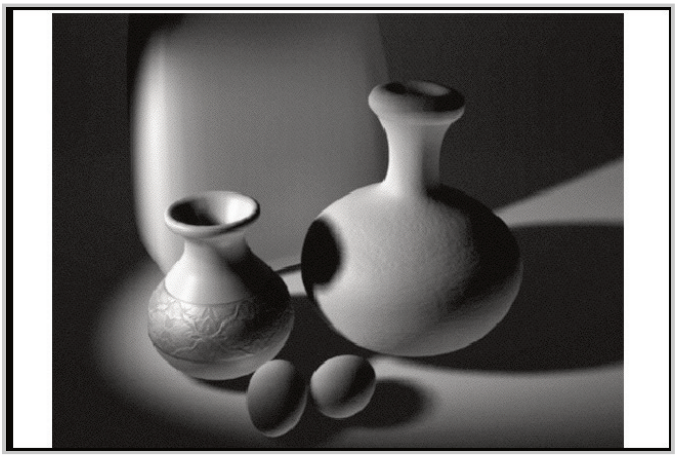


Alias Maya ?tutorial



Blender ?tutorial



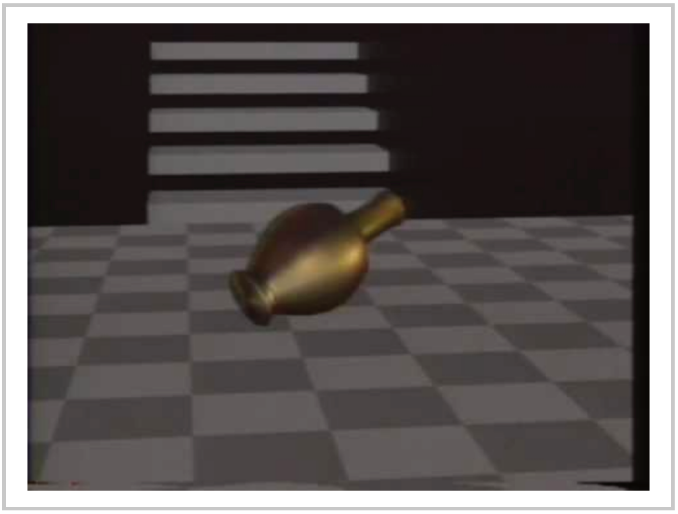




CG image of a samovar vase created at Cornell PCG.



Perlin Noise Functions



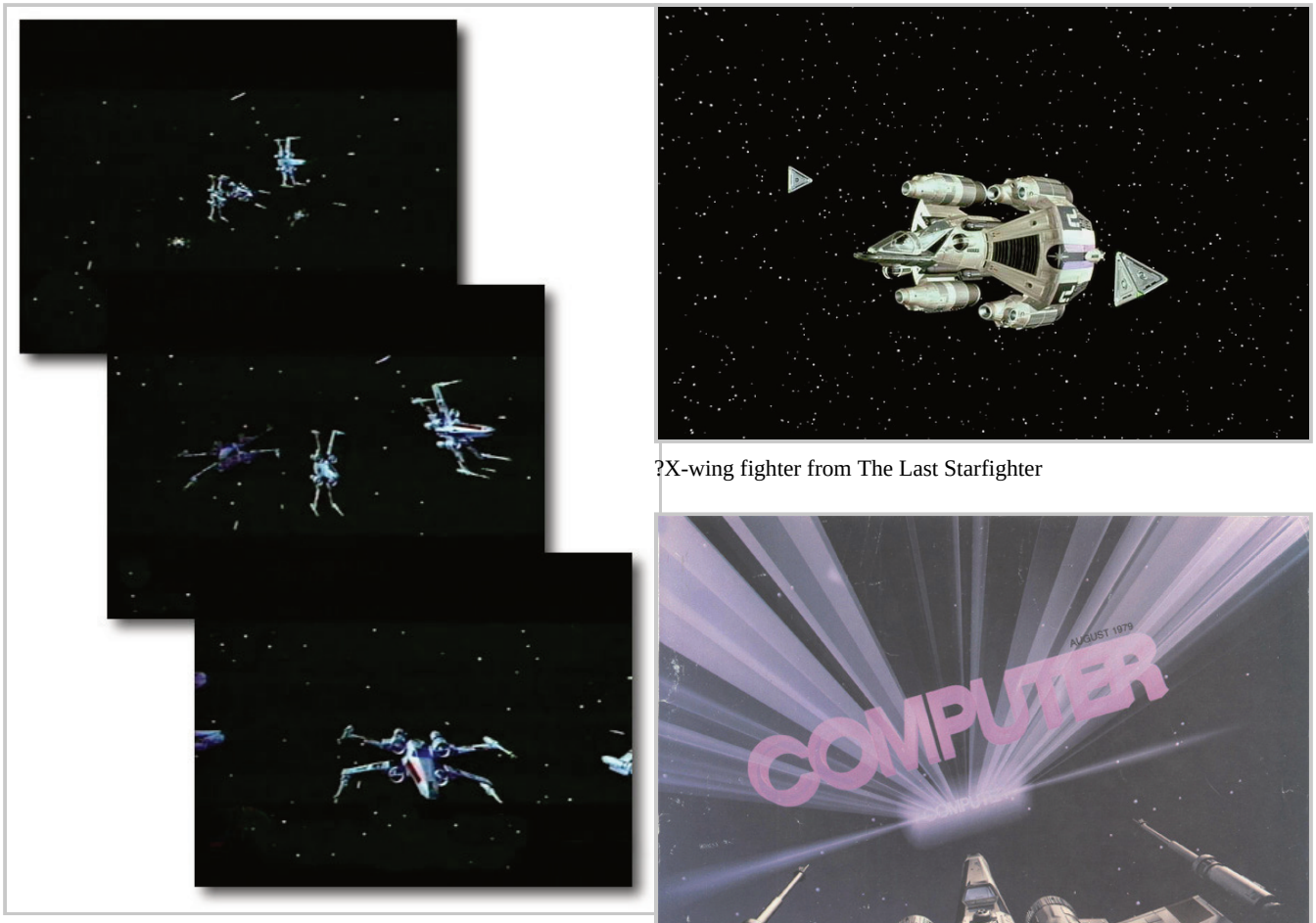
James Hahn



Hsuen Chung Ho

The X-Wing fighter, Starfighters, and other space ships

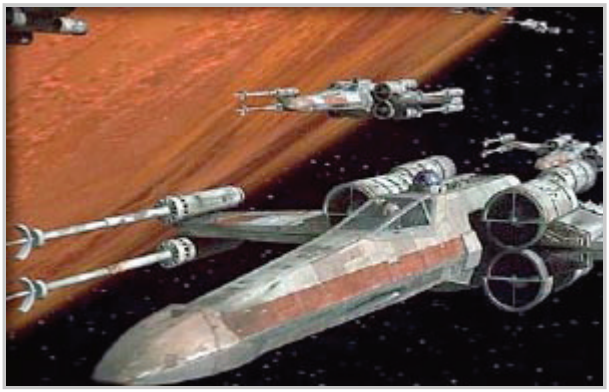
Because of their use in motion pictures such as *The Last Starfighter* and *Star Wars*, many early film tests that utilized CGI used space fighters such as the x-wing fighter and the gunstar as models.



?X-wing fighter from The Last Starfighter

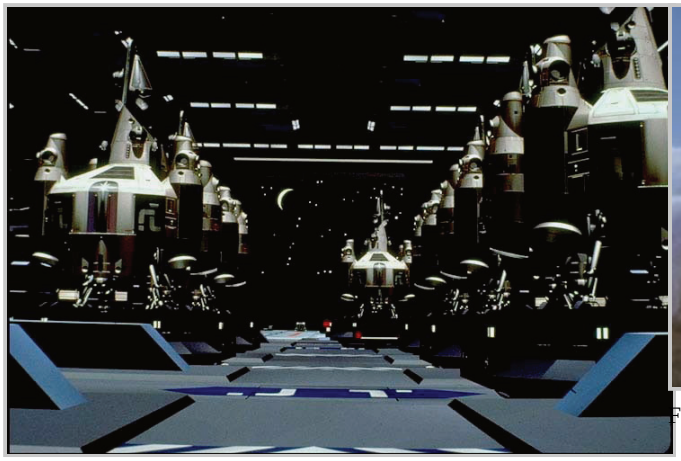


Cover of the August, 1979 IEEE Computer Magazine. Gary Demos produced this X-wing fighter image to convince George Lucas that CG could be used to make images for Star Wars.



X-Wing Fighter

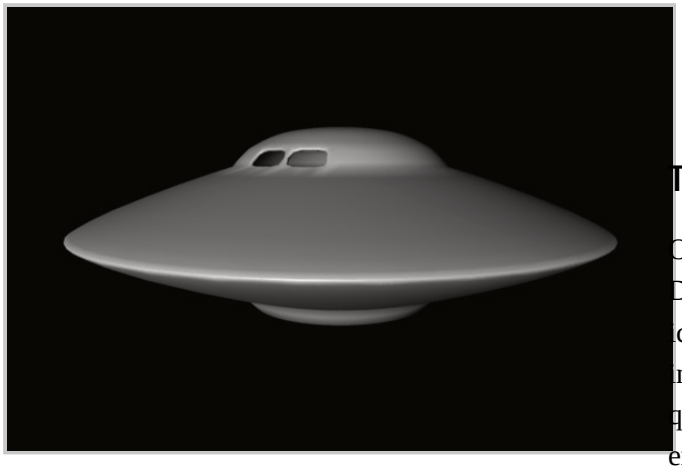




?Scene from The Last Starfighter



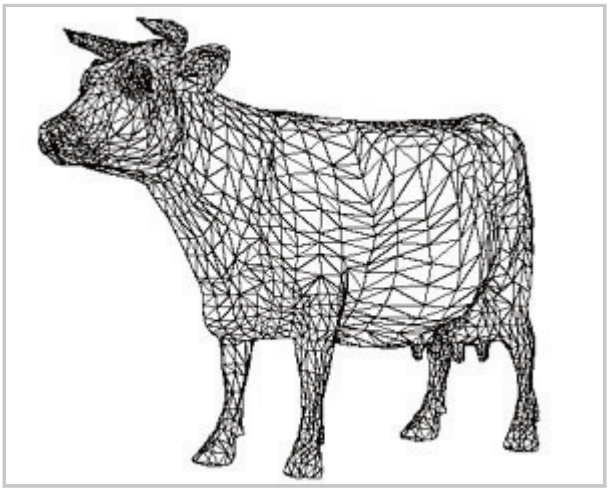
Flight of the Navigator



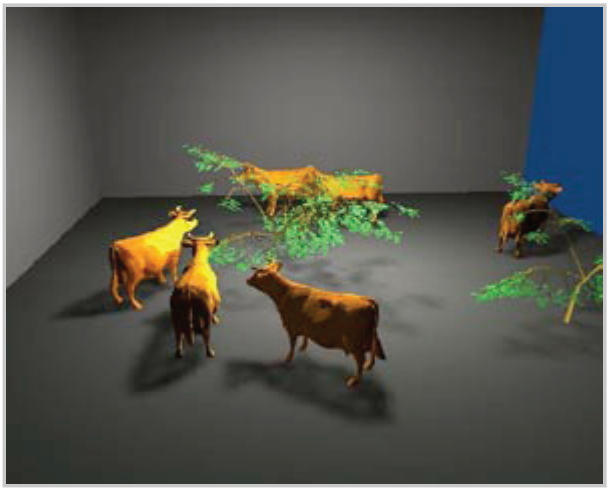
Autodesk

The Cow

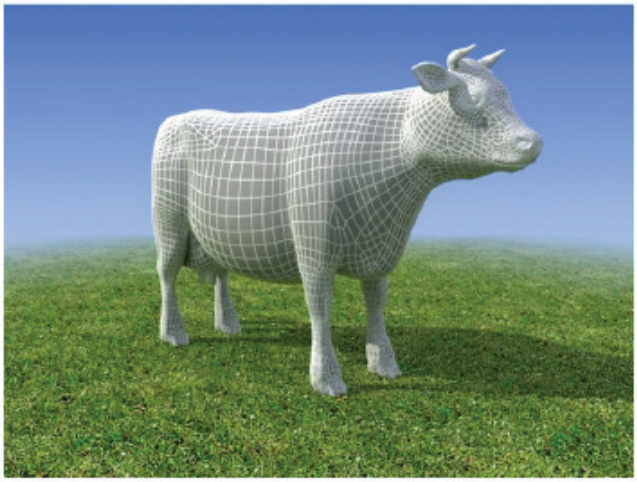
One of the many classic data sets from the Viewpoint Data Labs portfolio, the cow has achieved status as a CG icon, appearing in many demonstrations and exemplary images. It is a complex surface that has a recognizable quality, and has most often appeared out of context in environments that are not usual cow playgrounds.

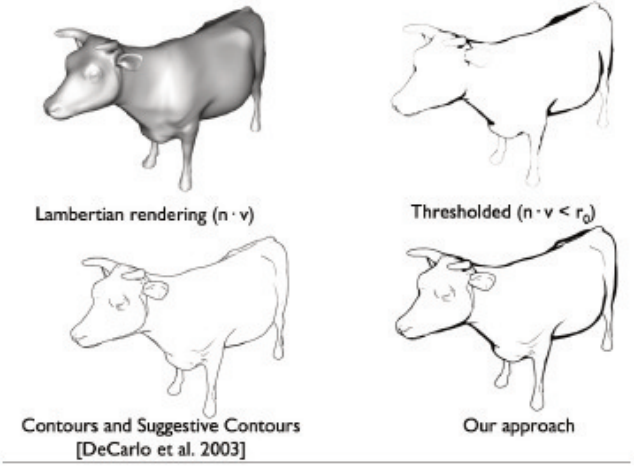






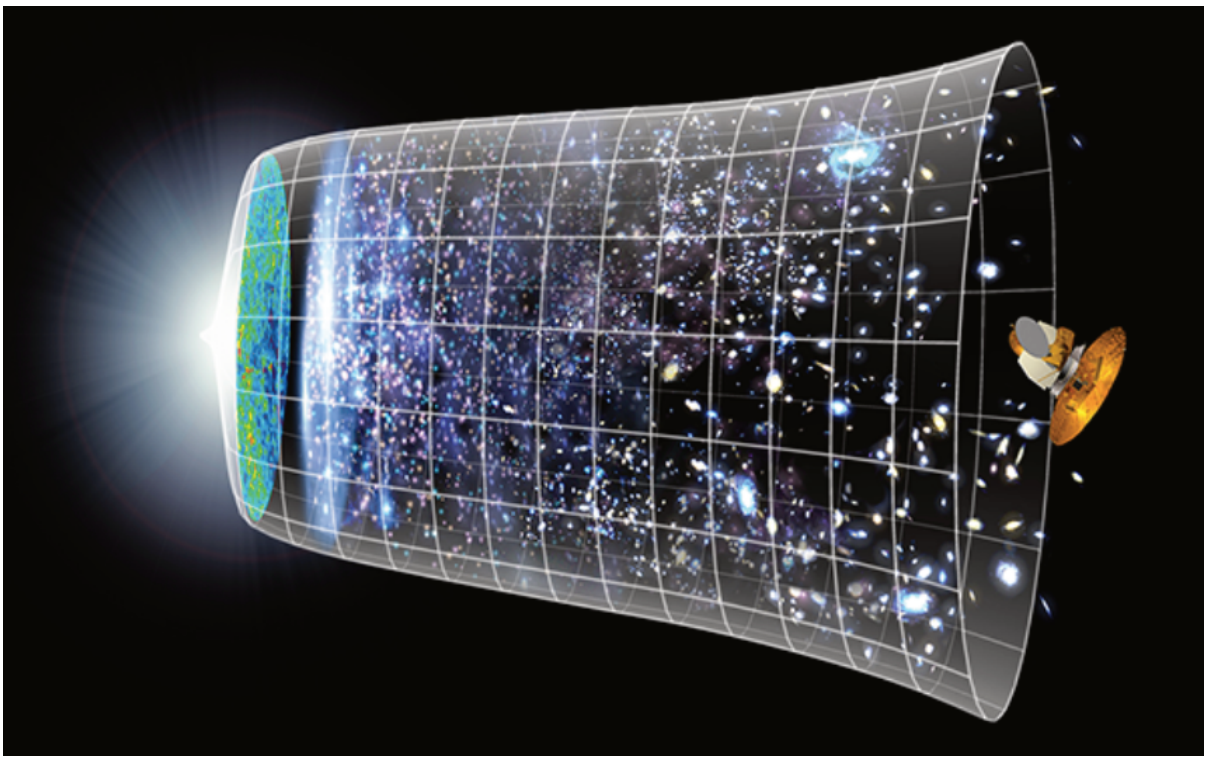





Lambertian rendering (n · v)
Thresholded (n · v < r_a)
Contours and Suggestive Contours
[DeCarlo et al. 2003]
Our approach

CG Historical Timeline

This timeline depicts key events in the evolution of the CGI discipline.



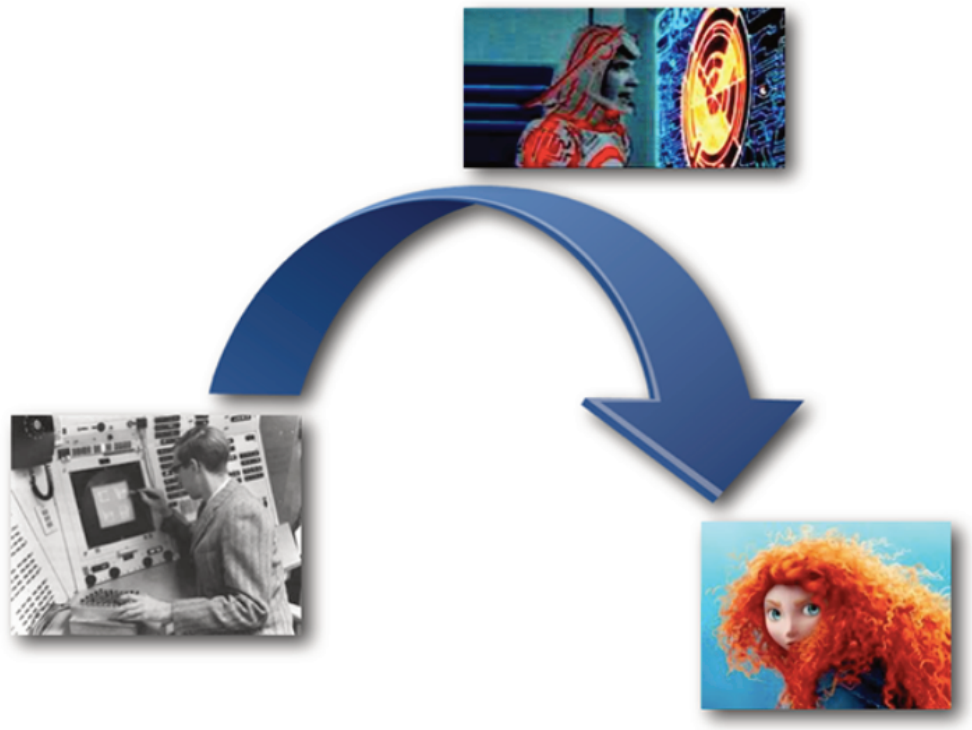
Timeline of the Universe (NASA)

Click below to jump to the decade:

Pre-1950s
1950s
1960s
1970s
1980s

1990s
2000s

The following timeline depicts key events in the evolution of the CGI discipline. It is not exhaustive, and some of the dates are controversial, as some references give one date and others give a different date. Some dates refer to when a contribution began, and others when a contribution was made public. We have tried to determine which is the appropriate date, but for some events the records are minimal.



Pre-1950s

1200

- Chinese Abacus

1617

- Napier’s bones



Napier’s Bones

1450

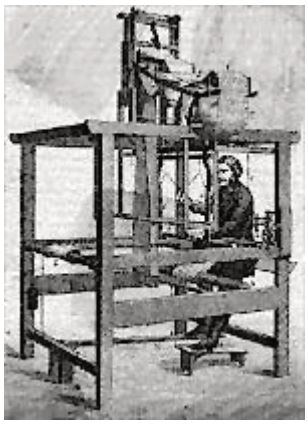
- Gutenberg press

1687

- Principia Mathematica – Isaac Newton

1801

- Jacquard loom



Jacquard Loom

1811

- Luddites riot

1826

- Photography (Niepce)

1830

- Babbage Analytical Engine designed

1842

- FAX (Alexander Bain)

1843

- Morse’s telegraph installed between Philadelphia and Washington

1864

- Maxwell electromagnetic wave theory becomes basis for radio wave propagation

1877

- Edison invents phonograph



Phonograph

1884

- Nipkow (Germany) devises scanner for scanning and transmitting images

1885

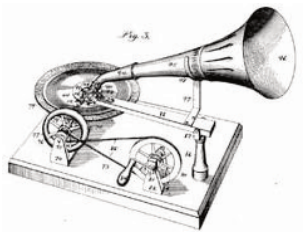
- CRT (Cathode Ray Tube)

1887

- Edison patents motion picture camera

1888

- Edison and Dickson design Kinetoscope – (motion pictures from successive photos on a cylinder)
- Berliner invents gramophone
- Oberlin Smith publishes basics of magnetic recording



Gramaphone

1890

- Hollerith introduces an automated punch-card driven tabulation device for the Census Bureau

1891

- Dickson uses Edison’s kinetograph to record motion pictures

1898

- Poulsen invents the Telegraphone, the first magnetic recording device

1905

- *Fleming electron tube*
- *Einstein's Theory of Relativity*



Fleming Tube

1906

- de Forest develops Audion vacuum tube amplifier

1923

- Zworykin develops Iconoscope at Westinghouse

1926

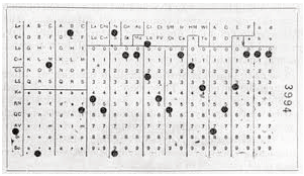
- First television (J.L. Baird)?• 1st teleconference – between Washington and New York

1927

- Philo Farnsworth invents fully electronic TV (First all-electronic TV is made by RCA in 1932)?• Motion picture film standardized at 24 fps

1928

- Hollerith introduces the 80-column "punch card"



Punch Card

1929

- BBC begins broadcasting

1930

- Philo Farnsworth receives patents for transmitting images by electronic means

1931

- 1st stereo recordings

1936

- The Magnetophone is 1st true magnetic tape recorder



Magnetophone

1938

- Valensi proposes color TV

1939

- Bill Hewlett and Dave Packard design the Audio Oscillator

1941

- First U.S. regular TV broadcast?• 1st TV commercial (for Bulova watches)

1945

- Whirlwind computer project starts at MIT

1946

- ENIAC computer built at University of Pennsylvania

1947

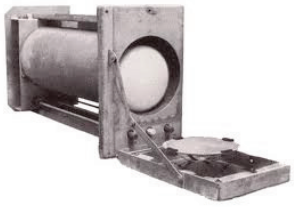
- Shockley, Bardeen and Brattain of Bell Labs invent transistors (“transfer resistance”)

1948

- Cable TV is installed

1949

- John Whitney enters first International Experimental Film Competition in Belgium
- Williams tube (CRT storage tube);
- Whirlwind computer built;
- Core memory developed by Wang of Harvard



Williams Tube

1950s

1950

- Cybernetics and Society – Norbert Weiner (MIT)
- Ben Laposky uses oscilloscope to display waveforms which were photographed as artwork

1951

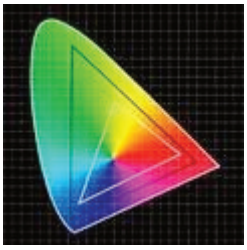
- Graphics display on vectorscope on Whirlwind computer in first public demonstration

1952

- Mr. Potato Head invented; later starred in Toy Story
- *Air Force Project Blue Book* organized to categorize UFO sightings

1953

- NTSC broadcast code



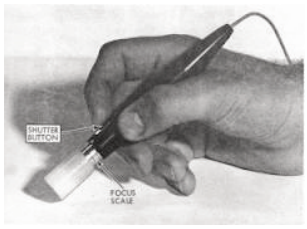
NTSC Spectrum

1954

- FCC authorizes color TV broadcast
- FORTRAN – John Backus

1955

- Disneyland opens
- SAGE system at Lincoln Lab uses first light pen (Bert Sutherland)



Light Pen

1956

- Lawrence Livermore National Labs connects graphics display to IBM 704; use film recorder for color images
- Ray Dolby, Charles Ginsberg and Charles Anderson of Ampex develop the first videotape recorder
- Alex Poniatoff (Ampex) introduces the VR1000 videotape recorder (2″tape) – the first practical broadcast quality VTR

1957

- 1st image-processed photo at National Bureau of Standards

- Max Mathews demonstrates first computer (IBM 704) synthesis of music (Music I) at Bell Labs
- Digital Equipment Corporation founded

DEC Logo

1958

- Numerical controlled digital drafting machines, APT II (Automated Programming Tools)- MIT
- CalComp 565 drum plotter
- Saul Bass creates titles for Hitchcock's Vertigo
- Integrated circuit (IC, or Chip) invented by Jack St. Clair Kilby of Texas Instruments and Robert Noyce of Fairchild Electronics
- John Whitney Sr. uses analog computer to make art

1959

- First film recorder – General Dynamics Stromberg Carlson 4020 (uses Charactron tube)
- TX-2 computer at MIT uses graphics console
- Béla Julesz creates random-dot stereogram
- GM begins DAC program



Random Dot Stereogram

1960s

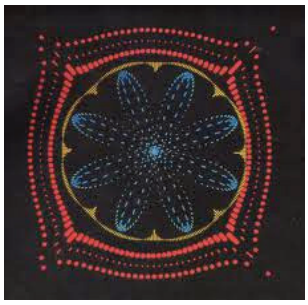
1960

- William Fetter of Boeing coins the term "computer graphics" for his human factors cockpit drawings
- John Whitney Sr. founds Motion Graphics, Inc.
- LISP developed by John McCarthy
- DEC PDP-1 introduced

1961

- *Spacewars*, 1st video game, developed by Steve Russell at MIT for the PDP-1

- Catalogue (John Whitney)



Whitney

1962

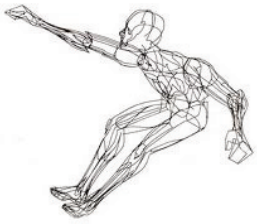
- Information International Inc. (Triple I) founded
- Itek begins Electronic Drafting Machine project
- *Mr. Computer Image ABC* produced on Scanimate by Lee Harrison

1963

- 1st computer art competition, sponsored by Computers and Automation
- Sketchpad developed beginning in 1961 by Ivan Sutherland at MIT is unveiled (Ref: Sutherland, Ivan E. Sketchpad: *A Man-Machine Graphical Communication System*. Proceedings of the AFIPS Spring Joint Computer Conference Washington, D.C.: 1963, p. 329-346.)
- Mouse invented by Doug Englebart of SRI
- Coons' patches
- Early computer generated film by Edward Zajac (Bell Labs)
- BEFLIX developed at Bell Labs by Ken Knowlton
- Charles Csuri makes his first computer generated artwork
- DAC-1, first commercial CAD system, developed in 1959 by IBM for General Motors is shown at JCC
- Lockheed Georgia starts graphics activity (Chase Chasen)
- Michael Noll (Bell Labs) starts his Gaussian Quadratic series of artwork
- Roberts hidden line algorithm (MIT)
- The Society for Information Display established
- Fetter of Boeing creates the "First Man" digital human for cockpit studies



Mouse



First Man

1964

- Project MAC (MIT)
- IBM 2250 console ($125,000) introduced with IBM 360 computer
- *Poem Field* by Stan Vanderbeek and Ken Knowlton
- Itek Digigraphic Program (later Control Data graphics system)
- The BASIC programming language developed by Kurtz and Kemeny
- Ruth Weiss introduces drawing software that performs hidden line elimination (Ref: Weiss, Ruth E. *BE VISION, a Package of IBM 7090 FORTRAN Programs to Drive Views of Combinations of Plane and Quadric Surfaces*. Journal of the ACM 13(4) April 1966, p. 194-204.)

- RAND tablet input device (commercially known as Grafacon)
- Compact cassette tape (Phillips)
- New York World's Fair
- Electronic character generator



Cassette Tape Deck

1965

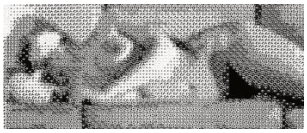
- 1st computer art exhibition, at Technische Hochschule in Stuttgart
- 1st U.S. computer art exhibition, at Howard Wise Gallery in New York
- Dolby Laboratories founded by Ray Dolby, inventor of the first videotape recorder (1956)
- Adage founded
- Roberts introduces homogeneous coordinates (Ref: Roberts, Lawrence G. 1965. *Homogenous Matrix Representation and Manipulation of N-Dimensional Constructs*, MS-1505. MIT Lincoln Laboratory, Lexington, Mass.)
- Utah computer science department founded
- Bresenham Algorithm for plotting lines (Ref: *Bresenham, J. E. Algorithm for Computer Control of a Digital Plotter*. IBM Systems Journal 4(1) 1965, p. 25-30.)
- Tektronix Direct View Storage Tube (DVST)
- CADAM developed at Lockheed; CADD developed at McDonnell Douglas
- Project DEMAND consortium (IBM, Lockheed, McDonnell Douglas, Rockwell, TRW, Rolls Royce)
- BBN Teleputer uses Tektronix CRT



Tektronix DVST

1966

- *Odyssey*, home video game developed by Ralph Baer of Sanders Assoc., is 1st consumer CG product
- Group 1 FAX machines (using CCITT compression)
- Lincoln Wand developed
- Plasma Panel introduced (first developed at Illinois in 1964 as part of the PLATO project)
- *Studies in Perception I* by Ken Knowlton and Leon Harmon (Bell Labs)
- MAGI founded by Phil Mittleman
- Joint Defense Department / Industry symposium on CAD/NC held in Oklahoma City
- Experiments in Art and Technology (E.A.T.) started in New York by artist Robert Rauschenberg and Bell Labs engineer Billy Klüver



Studies in Perception

- IBM awards Artist-in-Residence to John Whitney, Sr.
- Loutrel hidden line algorithm

1967

- Appel hidden line algorithm (Ref: Appel, Arthur. *The Notion of Quantitative Invisibility and the Machine Rendering of Solids*. Proceedings of the
- ACM National Conference 1967, p. 387-393.)
- Steven Coons publishes his surface patch "little red book" (Ref: Coons, Steven A. 1967. *Surfaces for Computer-aided Design of Space Forms* , Project MAC Report MAC-TR-41. Massachusetts Institute of Technology, Cambridge, Mass.)
- *Sine Curve Man* and *Hummingbird* created by Chuck Csuri
- Adage real time 3D line drawing system
- Lee Harrison's ANIMAC graphic device
- GE introduces first full color real time interactive flight simulator for NASA – Rod Rougelet
- MIT's Center for Advanced Visual Studies founded by Gyorgy Kepes
- Instant replay and Slo-Mo introduced using Ampex HS-100 disc recorder
- Cornell's program started in Architecture by Don Greenberg
- 1/2 inch open reel video tape recorder



Sine Curve Man

1968

- DEC 338 intelligent graphics terminal
- Tektronix 4010
- Intel founded
- University of Utah asks Dave Evans to form a CG department in computer science
- Warnock algorithm
- Watkins algorithm
- Edsger Dijkstra writes article Go To Statement Considered Harmful which signals beginning of structured programming
- Cybernetic Serendipity: *The Computer and the Arts* exhibition at London Institute of Contemporary Arts



Tektronix Display

- Csuri's *Hummingbird* purchased by Museum of Modern Art for permanent collection
- *Permutations* – John Whitney, Sr.
- Sutherland Head Mounted Display (Sword of Damocles), developed in 1966, shown (AFIPS Conference) (Ref: Sutherland, Ivan E. *A Head-Mounted Three-Dimensional Display*. Proceedings of the AFIPS Fall Joint Computer Conference Washington, D.C.: Thompson Books, 1968, p. 757-764.)
- Evans & Sutherland Calma, Computek, Houston Instrument, Imlac founded
- ARDS terminal, Computek 400 terminal
- LDS-1 ($250,000) from E&S introduces line clipping



Hummingbird



LDS-1

1969

- Computer Image Corporation founded
- UNIX developed by Thompson and Ritchie at Bell Labs (in PDP-7 assembly code)
- SCANIMATE commercialized – Lee Harrison
- Genesys animation system – Ron Baecker
- GRAIL (Graphics Input Language) developed at Rand
- Computer Space arcade game built by Nolan Bushnell
- Xerox PARC founded
- Lee Harrison's CAESAR animation system
- Bell Labs builds first framebuffer (3 bits)
- Sony U-Matic 3/4″ video cassette
- Intel introduces the 1 KB RAM chip
- 1st use of CGI for commercials – MAGI for IBM
- Graphical User Interface (GUI) developed by Xerox (Alan Kay)
- SIGGRAPH formed (began as special interest committee in 1967 by Sam Matsa and Andy vanDam)
- ComputerVision, Applicon, Vector General founded
- ARPANET is born



U-matic Tape

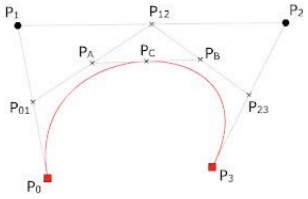
1970s

1970

- Sonic Pen 3-D input device
- ISSCO (Integrated Software Systems Corporation) founded (marketed DISSPLA software) by Peter Preuss
- Watkins algorithm for visible surfaces
- Lillian Schwartz produces *Pixellation* at Bell Labs
- Pascal programming language developed by Wirth
- Imlac PDS-1 programmable graphics computer marketed
- John Staudhammer starts NCSU Graphics Lab at NC State
- Pierre Bezier from Renault develops Bezier freeform curve representation



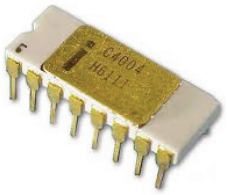
Sonic Pen



Bezier Curve

1971

- Gouraud shading (Ref: Gouraud, Henri. *Continuous Shading of Curved Surfaces*. IEEE Transactions on Computers C-20(6), June 1971, p. 623-29.)
- Ramtek founded
- GINO (graphics input output specification) – Cambridge University
- Intel 4004 4-bit processor
- *Interactive Graphics for Computer-Aided Design* (Prince) published
- MCS (Manufacturing and Consulting Services) founded by Patrick Hanratty, considered the “father” of mechanical CAD/CAM – introduces ADAM
- CAD software, which is the heart of many modern software systems
- Robert Abel and Associates founded
- Floppy disk (8″) – IBM



Intel 4004

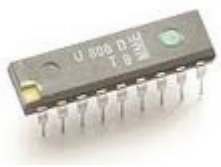


Floppy Disk

1972

- MAGI Synthevision started
- CGRG founded at Ohio State
- NASA IPAD (Integrated Program for Aerospace Vehicle Design) initiative started
- Graphics Standards Planning Committee organized by ACM-SIGGRAPH
- The @ symbol selected for email addresses by BBN
- C language developed by Ritchie

- Emmy awarded to Lee Harrison for SCANIMATE
- Alto computer introduced by Xerox PARC (Alan Kay)
- Intel 8008 8-bit processor
- Megatek, Summagraphics, Computervision, Applicon founded
- Utah hand (Catmull) and face (Parke) animations produced (Ref: Catmull, Edwin. *A System for Computer Generated Movies*. Proceedings of the ACM National Conference August 1972, p. 422-431. and Parke, Frederic I. *Computer Generated Animation of Faces*. Proceedings of the ACM National Conference 1972, p. 451-457.)
- Computer Graphics and Image Processing journal begins publication
- 8-bit frame buffer developed by Dick Shoup at Xerox PARC
- Sandin Image Processor – Dan Sandin, Univ. Illinois-Chicago Circle
- Atari formed (Nolan Bushnell)
- Newell, Newell and Sancha visible surface algorithm (Ref: Newell, M. E., R. G. Newell and T. L. Sancha. *A Solution to the Hidden Surface Problem*. Proceedings of the ACM National Conference 1972, p. 443-450)
- Video game Pong developed for Atari
- Graphics Symbiosis System (GRASS) developed at Ohio State by Tom DeFanti



Intel 8008



Pong

1973

- E&S begins marketing first commercial frame buffer
- Ethernet – Bob Metcalf (Harvard)
- Quantel founded
- *Westworld* – uses 2D graphics
- Circle Graphics Habitat founded at Univ. Illinois Chicago (Tom DeFanti & Dan Sandin)
- Moore's Law (the number of transistors on a microchip will double every year and a half) by Intel's chairman, Mr. Gordon Moore
- Nolan Bushnell's video game Computer Space appears in movie *Soylent Green*

- First SIGGRAPH conference (Boulder)
- 3/4 inch Portapack replaces 16mm film for news gathering
- Richard Shoup develops PARC raster display
- Rich Riesenfeld (Syracuse) introduces b-splines for geometric design (Ref: R.F. Riesenfeld. *Applications of B-Spline Approximation to Geometric Problems of Computer Aided Design*. PhD Dissertation, Syracuse University , 1973.)
- *Principles of Interactive Computer Graphics* (Newman and Sproull) first comprehensive graphics textbook is published



Portapak

1974

- Motion Pictures Product Group formed at III by John Whitney, Jr. and Gary Demos
- Alex Schure opens CGL at NYIT, with Ed Catmull as Director
- Barnhill and Riesenfeld introduce the name “Computer-Aided Geometric Design” (CAGD)
- SuperPaint developed by Dick Shoup and Alvy Ray Smith
- TCP protocol (Vint Cerf, Bob Kahn)
- DEC VT52 incorporated the first addressable cursor in a graphics display terminal
- Intel (Zilog) 8080
- Z-buffer developed by Ed Catmull (University of Utah) (Ref: E. Catmull. *A Subdivision Algorithm for Computer Display of Curved Surfaces*, Ph.D. Thesis, Report UTEC-CSc-74-133, Computer Science Department, University of Utah, Salt Lake City, UT, 1974)



VT 52

- *Futureworld* (sequel to *Westworld*) uses 3D CGI (III)
- *Hunger/La Faim* produced by Peter Foldes at National Research Council of Canada; wins Cannes Film Festival Prix de Jury award for animation

1975

- Phong shading – Bui-Toung Phong (University of Utah) (Ref: Bui-Tuong, Phong. *Illumination for Computer Generated Pictures*. Communications of the ACM 18(6) June 1975, p. 311-317.)
- Sony Betamax recorder

- USAF ICAM (Integrated Computer Aided Manufacturing) initiative started
- Cray 1 introduced
- Altair 8800 computer
- fractals – Benoit Mandelbrot (IBM)
- Winged edge polyhedra representation (Bruce Baumgart)
- Catmull curved surface rendering algorithm (Ref: Catmull, Edwin. *Computer Display of Curved Surfaces*. Proceedings of the IEEE Conference on Computer Graphics, Pattern Recognition and Data Structures (IEEE Cat. No. 75CH0981-1C) 1975, p. 11-17.)
- Bill Gates starts Microsoft
- Quantel (QUANtized TELevision) introduces the DFS3000 Digital Framestore
- Martin Newell (Utah) develops CGI teapot (physical teapot now in the Computer Museum in Boston)
- JPL Graphics Lab developed (Bob Holzman)
- *Arabesque* completed (John Whitney)
- *Anima* animation system developed at CGRG at Ohio State (Csuri)



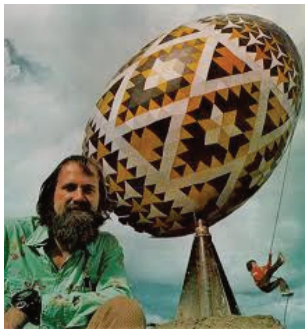
Betamax



Teapot

1976

- MITs Visible Language Workshop founded by Muriel Cooper
- Ed Catmull develops “tweening” software (NYIT)
- Jim Clark’s Hierarchical model for visible surface detection [Ref: J. H. Clark. *Hierarchical geometric models for visible surface algorithms*. Communications of the ACM, 19(10):547– 554, 1976.)
- N. Burtnyk , M. Wein, *Interactive skeleton techniques for enhancing motion dynamics in key frame animation*, CACM, V19, #10, Oct 1976, 564-569
  Dolby sound
- Jim Blinn develops reflectance and environment mapping (University of Utah)
- Nelson Max’s sphere inversion film
- Ukrainian Pysanka Egg erected in Vegraville, Canada by Ron Resch (University of Utah) to commemorate the RCMP
- Sony Beta home video
- Floppy disk (5 1/4″)
- Apple 1 (Wozniak)
- IFIP (The International Federation of Information Processing) conference at Seillac in France on “The Methodology of Computer Graphics” begins standardization process
- Computer Graphics Newsletter started by Joel Orr; becomes Computer



Pysanka

Graphics World in 1978

- Peter Fonda's head digitized and rendered by III for *Futureworld*
- Ampex VPR-1 Type C 1″ video recorder
- Wang word processing
- *Artist and Computer*, by Ruth Leavitt
- *Mathematical Elements for Computer Graphics* (David Rogers) published
- Steve Jobs and Steve Wozniak start Apple computer.



VPR-1

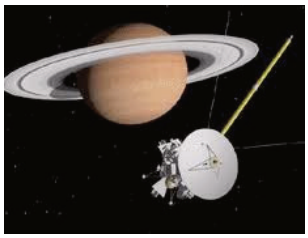
1977

- Apple Computer incorporated
- VHS (Video Home System) format – Matsushita
- JVC VHS home video
- Apple II released
- TRS-80 introduced
- Frank Crow introduces antialiasing (Ref: Franklin C. Crow, *The aliasing problem in computer-generated shaded images*, Communications of the ACM, v.20 n.11, p.799-805, Nov. 1977)
- Jim Blinn introduces a new illumination model that considers surface "facets" (Ref: *Models of light reflection for computer synthesized pictures*, James F. Blinn , Proceedings of the 4th annual conference on Computer graphics and interactive techniques July 1977, V11, #2, pp192-198)



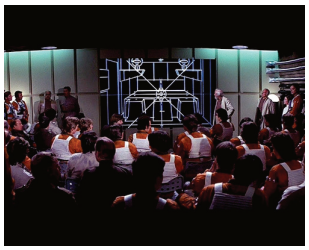
TRS-80

- Computer Graphics World begins publication (started by Joel and N'omi Orr as Computer Graphics Newsletter)
- Academy of Motion Pictures Arts and Sciences introduces Visual Effects category for Oscars
- Nelson Max joins LLL
- Jim Blinn joins JPL
- R/Greenberg founded (Richard and Robert Greenberg)
- SIGGRAPH CORE Graphics standard
- Ampex ESSTM (Electronic Still Store) system introduced for network sports slo-mo;adapted for use as animation sequential storage device
- GKS (Graphical Kernal System) graphics standard introduced
- Fuchs multiprocessor visible surface algorithm (Ref: Fuchs, Henry. *Distributing A Visible Surface Algorithm Over Multiple Processors*. Proceedings of the ACM National Conference 1977, p. 449-451.)



Blinn animation

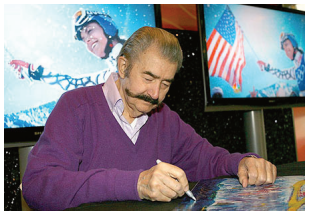
- Larry Cuba produces Death Star simulation for *Star Wars* using Grass at UICC developed by Tom DeFanti at Ohio State



Cuba graphics

1978

- Tom DeFanti's GRASS system rewritten for Bally home computer (Zgrass)
- E&S goes public
- AT&T and Canadian Telidon introduce videotex graphics standard (NAPLPS)
- Digital Effects founded (Judson Rosebush, Jeff Kleiser, et al)
- Lance Williams curved shadows paper (Ref: Lance Williams, *Casting curved shadows on curved surfaces*, Proceedings of the 5th annual conference on Computer graphics and interactive techniques, p.270-274, August 23-25, 1978)
- Ikonas frame buffer – England/Whitton
- Leroy Neiman uses Ampex AVA-1TM video art system to draw (on air) football players in Super Bowl XII
- 1st CGI film title – Superman (R. Greenberg)
- Computer Graphics World begins publication
- James Blinn produces the first of a series of animations titled *The Mechanical Universe*
- DEC VAX 11/780 introduced
- Video laser disc
- Bump mapping introduced (Blinn) (Ref: *Simulation of wrinkled surfaces*, James F. Blinn, Proceedings of the 5th annual conference on Computer graphics and interactive techniques August 1978, V12, #3, pp 286-292.)



Leroy Nieman



VAX 11-780

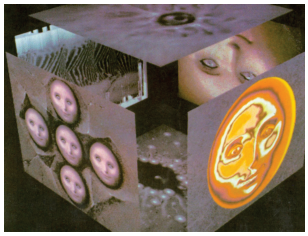
1979

- National Computer Graphics Association (NCGA) organized by Peter Preuss of ISSCO and Joel Orr
- IGES graphics file format specified
- IBM 3279 color terminal
- E&S PS-300
- Motorola 68000 32-bit processor
- Atari 8-bit computers introduced
- Disney produces *The Black Hole* using CGI for the opening



IBM 3279

- *Sunstone* – Ed Emshwiller (NYIT)
- George Lucas hires Ed Catmull, Ralph Guggenheim and Alvy Ray Smith to form Lucasfilm



Frame from Sunstone

1980s

1980

- *Vol Libre* – Loren Carpenter of Boeing
- Apollo Computer founded – introduces the 68000 based DN100 workstation
- Turner Whitted of Bell Labs publishes ray tracing paper (Ref: Turner Whitted, *An improved illumination model for shaded display*, Communications of the ACM, v.23 n.6, p.343-349, June 1980)
- First NCGA conference – Arlington, Virginia – Steven Levine, President
- *Donkey Kong* introduced by Nintendo (Mario named in US release)
- IBM licenses DOS from Microsoft
- Apple Computer IPO – 4.6M shares @ $22
- Aurora Systems founded by Richard Shoup
- SIGGRAPH Core standard reorganized as ANSC X3H3.1 (PHIGS)



Apollo Computer



Donkey Kong

- EUROGRAPHICS (The European Association for Computer Graphics) formed; first conference at Geneva
- Disney contracts Abel, III, MAGI and DE for computer graphics for the movie *Tron*
- MIT Media Lab founded by Nicholas Negroponte
- Pacific Data Images founded by Carl Rosendahl
- Computer hard disk drive – Seagate
- Hanna-Barbera, largest producer of animation in the U.S., begins implementation of computer automation of animation process

- Sony Walkman
- Quantel introduces Paintbox



Walkman

1981

- Sony Betacam
- Tom DeFanti expands GRASS to Bally Z-50 machine (ZGRASS) – University Illinois – Chicago Circle
- IBM introduces the first IBM PC (16 bit 8088 chip)
- DEC introduces VT100
- IEEE *Computer Graphics and Applications* published by IEEE Computer Society and NCGA
- Ampex ADO® system introduced; garners an Emmy award in 1983
- Digital Productions formed by Whitney and Demos
- Cranston/Csuri Productions founded by Chuck Csuri, Robert Kanuth and Jim Kristoff.
- R/Greenberg opens CGI division (Chris Woods)
- MITI Fifth Generation Computer Project announced by Japanese Ministry of International Trade and Industry
- REYES renderer written at LucasFilm
- Penguin Software (now Polarware) introduces the Complete Graphics System
- *Looker* includes the virtual human character Cindy (Susan Dey) – 1st film with shaded graphics(III)
- *Adam Powers, the Juggler* produced by III
- *Carla's Island* – Nelson Max



Adam Powers

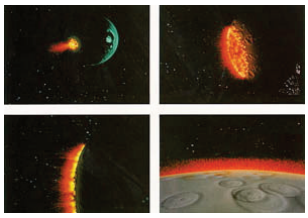
1982

- *The Last Starfighter* (Digital Productions) begins production
- *Tron* released
- The Geometry Engine (Clark) (Ref: Clark, James H. *The Geometry Engine: A VLSI Geometry System for Graphics*. Computer Graphics (SIGGRAPH 82 Proceedings) 16(3) July 1982, p. 127-133.)
- Jim Clark founds Silicon Graphics Inc.
- Sun Microsystems founded (sun := Stanford University Network)
- Alain Fournier , Don Fussell , Loren Carpenter, *Computer Rendering of Stochastic Models*. Communications of the ACM, v.25 n.6, p.371-384, June 1982 (Fractal Rendering paper)
- *Skeleton Animation System* (SAS) developed at CGRG at Ohio State (Dave Zeltzer)

- Sony still frame video camera (Mavica)
- ACM begins publication of TOG (*Transactions on Graphics*)
- Tom Brighham develops morphing (NYIT)
- Adobe founded by John Warnock
- Toyo Links established in Tokyo
- Quantel Mirage
- Symbolics Graphics Division founded
- EPCOT Center opens
- Atari develops the data glove.
- *Where the Wild Things Are* test (MAGI) – digital compositing used to combine CG backgrounds and traditional animation
- AutoDesk founded; AutoCAD released
- ILM computer graphics division develops "Genesis effect" for *Star Trek II – The Wrath of Khan*



Mavica



Frames from the Genesis Effect

1983

- Particle systems (Reeves – Lucasfilm) (Ref: Reeves, William T. *Particle Systems*: A *Technique for Modeling a Class of Fuzzy Objects*. Computer Graphics (SIGGRAPH 83 Proceedings) 17(3) July 1983, p. 359-376.)
- SGI IRIS 1000 graphics workstation
- Non-Uniform Rational B-Splines (NURBS) introduced by Tiller (Note: this date is somewhat misleading, since the concept built on the work of Vesprille (1975), Riesenfeld (1973), Knapp (1979), Coons (1968) and Forrest (1972))
- *Road to Point Reyes* created – Lucasfilm
- *The Last Starfighter* released
- Jim Blinn receives the first (1983) ACM SIGGRAPH CG Achievement Award
- Ivan Sutherland receives the first (1983) ACM SIGGRAPH Steven A. Coons Award
- Steve Dompier's "Micro Illustrator"
- UNIX System V
- Utah Raster Toolkit introduced (Spencer Thomas)
- Autodesk introduces first PC-based CAD software
- Alias founded in Toronto by Stephen Bingham, Nigel McGrath, Susan McKenna and David Springer mip-mapping introduced for efficient texture mapping (Williams – NYIT) (Ref: Williams, Lance. *Pyramidal Parametrics*. Computer Graphics (SIGGRAPH 83 Proceedings) 17(3) July 1983, p. 1-11.

- Sony and Philips introduce 1st CD player
- Wacom Co., Ltd started in Japan



Sony CD Player

1984

- Robert Abel & Associates produces the 1st computer generated 30 second commercial used for Super Bowl (*Brilliance*)
- Wavefront Technologies is the first commercially available 3D software package (founded by Mark Sylvester, Larry Barels and Bill Kovacs)
- Thomson Digital Image (TDI) founded
- Jim Clark receives the 1984 ACM SIGGRAPH CG Achievement Award
- International Resource Development report predicts the extinction of the keyboard in the next decade



Scene from Brilliance

- A-buffer (or alpha-buffer) introduced by Carpenter of Lucasfilm
- Distributed ray tracing introduced by Lucasfilm (Ref: Cook, Robert L., Thomas Porter and Loren Carpenter. *Distributed Raytracing*. Computer Graphics (SIGGRAPH 84 Proceedings) 18(3) July 1984, p. 137-145.)
- Cook shading model (Lucasfilm) (Ref: Cook, Robert L. *Shade Trees*. Computer Graphics (SIGGRAPH 84 Proceedings) 18(3) July 1984, p. 223-231.)
- 14.5 minute computer generated IMAX film (The Magic Egg) shown at SIGGRAPH 84 – 18 teams; 20 segments
- Universal Studios opens CG department
- First Macintosh computer is sold; introduced with Clio award winning commercial 1984 during Super Bowl
- McDonnel Douglas introduces the Polhemus 3Space digitizer and body Tracker
- The Cornell Box invented by Cohen
- Radiosity born – Cornell University (Ref: Goral, Cindy M., Kenneth E. Torrence, Donald P. Greenberg and Bennett Battaile.*Modeling the Interaction of Light Between Diffuse Surfaces*. Computer Graphics (SIGGRAPH 84 Proceedings) 18(3) July 1984, p. 213-222.)
- John Lasseter joins Lucasfilm
- Motorola 68020
- Digital Productions (Whitney and Demos) get Academy Technical Achievement Award for CGI simulation of motion picture photography



Cornell Box

- Lucasfilms introduces motion blur effects
- Porter and Duff compositing algorithm (Lucasfilm) (Ref: Porter, Thomas and Tom Duff. *Compositing Digital Images*. Computer Graphics (SIGGRAPH 84 Proceedings) 18(3) July 1984, p. 253-259.)
- The Adventures of Andre and Wally B. (Lucasfilm)



Motorola 68020

1985

- Commodore launches the new Amiga
- Loren Carpenter receives the 1985 ACM SIGGRAPH CG Achievement Award
- Pierre Bezier receives the 1985 ACM SIGGRAPH Steven A. Coons Award
- Sogitec founded (Xavier Nicolas)
- *Max Headroom* – computer-mediated live action figure



Amiga

- Judson Rosebush Co. started
- Abel Image Research takes Robert Abel & Associates to shaded graphics business
- *Tony de Peltrie* airs
- stereo TV
- *Biosensor* (Toyo Links)
- Cray 2
- GKS standard
- Quantel Harry is first non-linear editor
- UNIX X10R1
- CGW predicts 90s graphics workstation
- Targa 16 board (AT&T) goes to market
- Pixar Image Computer goes to market
- NeXT Incorporated founded by Steve Jobs and five former Apple senior managers
- Perlin's noise functions introduced (Ref: Perlin, Ken. *An Image Synthesizer*. Computer Graphics (SIGGRAPH 85 Proceedings) 19(3) July 1985, p. 287-296.)
- CD-ROMs High Sierra (ISO9660) standard introduced
- PostScript (Adobe – John Warnock)



Tony De Peltrie



Targa

- PODA creature animation system developed by Girard and Maciejewski at Ohio State (Ref: Girard, Michael and A. A. Maciejewski. *Computational Modeling for the Computer Animation of Legged Figures*. Computer Graphics (SIGGRAPH 85 Proceedings) 19(3) July 1985, p. 263-270.)
- Boss Films founded by Richard Edlund
- MIT Media Lab moves to new home
- *Young Sherlock Holmes* stained glass knight (Lucasfilm), *2010* (Boss Films)and *Looker* (DP)



Media Lab

1986

- *The Great Mouse Detective* was the first animated film to be aided by CG.
- Pixar purchased from Lucasfilm by Steve Jobs
- X-Window System (MIT Project Athena)
- Trancept Systems founded by Nick England and Mary Whitton – graphics board for Sun
- CGI group starts at Industrial Light and Magic (Doug Kay and George Joblove)
- Softimage founded by Daniel Langlois in Montreal
- Sun Microsystems goes public
- mental images founded in Berlin
- Computer Associates acquires ISSCO
- Microsoft goes public (IPO raises $61M; share prices go from $21 to $28)
- Apple IIgs introduced
- Silicon Graphics Incorporated IPO
- SGI IRIS 3000 (MIPS processor)
- Turner Whitted receives the 1986 ACM SIGGRAPH CG Achievement Award
- Jim Henson Waldo project introduces motion capture (Digital Productions)
- Kajiya's Rendering Equation (Ref: Kajiya, James T. *The Rendering Equation*. Computer Graphics (SIGGRAPH 86 Proceedings) 20(4) August 1986, p. 143-150.)
- Omnibus assumes Robert Able & Associates and Digital Productions in hostile takeovers by John Pennie and investors



Jim Henson – Waldo

- Whitney/Demos Productions founded
- Intel introduces 82786 graphics coprocessor chip ; Texas Instruments introduces TMS34010 Graphics System Processor
- NSFNet

- *Luxo Jr.* nominated for Oscar (first CGI film to be nominated – Pixar)
- TIFF (Aldus)
- Scitex founded for prepress



Luxo Jr.

1987

- GIF format (CompuServe), JPEG format (Joint Photographic Experts Group)
- *Willow* (Lucasfilm) popularizes morphing
- *Max Headroom* debuts
- LucasArts formed
- Adobe Illustrator
- CGM (Computer Graphics Metafile) standard
- Side Effects Software established
- VGA (Video Graphivs Array) invented by IBM
- Windows 2.0, MS/OS 2, Excel
- Sun 4 SPARC workstation
- Reynolds' flocking behavior algorithm (Symbolics) (Ref: Reynolds, Craig W. *Flocks, Herds and Schools: A Distributed Behavior Model*. Computer Graphics (SIGGRAPH 87 Proceedings) 21(4) July 1987, p. 25-34.)
- *Stanley and Stella in: Breaking the Ice*
- Rob Cook receives the 1987 ACM SIGGRAPH CG Achievement Award
- Don Greenberg receives the 1987 ACM SIGGRAPH Steven A. Coons Award
- Advanced Computing Center for the Arts and Design (ACCAD) founded at Ohio State (formerly CGRG)
- Omnibus closes, eliminating DP and Abel
- Cranston/Csuri Productions closes
- Marching Cubes algorithm (Lorensen and Cline – GE) (Ref: Lorensen, William and Harvey E. Cline. *Marching Cubes: A High Resolution 3D Surface Construction Algorithm*. Computer Graphics (SIGGRAPH 87 Proceedings) 21(4) July 1987, p. 163-170.)
- Metrolight Studios, RezN8 Productions, Kleiser/Walczak Construction Co., DeGraf/Wahrman founded



Sparc Station 4

1988

- PICT format (Apple)
- Apple sues Microsoft for copyright infringement for GUI
- GKS, PHIGS standards
- Prime Computer acquires Computervision

- Solid Texturing introduced (Perlin Noise Functions) (Ref: K. Perlin. *An image synthesizer*. Computer Graphics, 19(3):287–296, 1985)
- Al Barr receives the 1988 ACM SIGGRAPH CG Achievement Award
- Internet Worm infects servers all over the world
- Gary Demos founds DemoGraFX
- Open Software Foundation (OSF)
- NeXT Cube – For $6500, it features: 25-MHz 68030 processor and 68882 math coprocessor, 8 MB RAM, 17-inch monochrome monitor, 256 MB read/write magneto-optical drive, and object-oriented NexTSTEP operating system.
- JCGL purchased by NAMCO
- US Patent awarded to Pixar for RenderMan
- Who Framed Roger Rabbit mixes live action and animation
- Willow (Lucasfilm) uses morphing in a feature film
- D-2 composite video format introduced by Ampex
- Disney and Pixar develop CAPS (Computer Animation Paint System) (academy technical award in 1992)
- PIXAR wins Academy award for Tin Toy



NeXT Cube

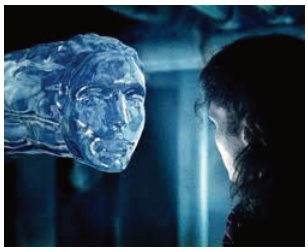
1989

- John Warnock receives the 1989 ACM SIGGRAPH CG Achievement Award
- David Evans receives the 1989 ACM SIGGRAPH Steven A. Coons Award
- 8MM videotape introduced by Sony
- Adobe Photoshop
- PHIGS+
- OSF Motif V1.0 released
- Intel 80486
- mental ray renderer released (integrated with Wavefront (1992), Softimage (1993), Maya (2002)) – awarded AMPAS Technical Achievement Award in 2002
- HP buys Apollo
- Computervision acquires Calma



8mm Tape

- ILM creates the Abyss
- PIXAR starts marketing RenderMan

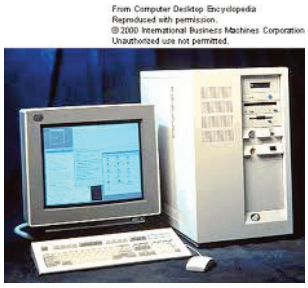


Abyss

1990s

1990

- Microsoft ships Windows 3.0
- NewTek Video Toaster
- First edition of Graphics Gems published by Academic Press (Andrew Glassner, editor)
- US Patent awarded to Pixar for point sampling
- Richard Shoup and Alvy Ray Smith receive the 1990 ACM SIGGRAPH CG Achievement Award
- 3D Studio (AutoDesk)
- Windows 3.0
- IBM RS6000 workstation
- John Wiley & Sons begins publishing The Journal of Visualization and Computer Animation



RS 6000

1991

- World Wide Web (CERN)
- Jim Kajiya receives the 1991 ACM SIGGRAPH CG Achievement Award
- Andy van Dam receives the 1991 ACM SIGGRAPH Steven A. Coons Award
- Disney and PIXAR agree to create 3 films, including the first computer animated full-length film Toy Story
- ILM produces Terminator 2
- The Academy of Motion Pictures Arts and Sciences Special Achievement Award for Visual Effects for Total Recall (Metrolight Studios)
- Beauty and the Beast (Disney)
- Symbolics Graphics Division sold to Nichimen Graphics
- Motorola 68040
- Kodak PhotoCD
- JPEG/MPEG
- SunSoft – software subsidiary of Sun Microsystems

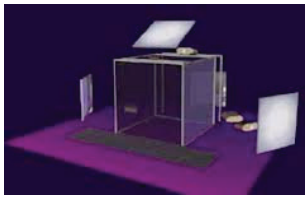
- SGI Indigo workstation
- Disney (Randy Cartwright, David Coons, Lem Davis, Tom Hahn, Jim Houston, Mark Kimball, Dylan Kohler, Peter Nye, Mike Shaantzis, David Wolf) get Academy Scientific and Engineering Award for CAPS production system.
- Ray Feeney, Richard Keeney and Richard Lundell get Academy Scientific and Engineering Award for the Solitair Film Recorder .



SGI Indigo

1992

- QuickTime introduced (Apple)
- Henry Fuchs receives the 1992 ACM SIGGRAPH CG Achievement Award
- Softimage goes public
- SGI acquires MIPS
- OpenGL (SGI) released
- University of Illinois debuts CAVE virtual reality technology at SIGGRAPH 92
- Lawnmower Man (Effects by Angel Studios and Xaos)
- US Patent awarded to Pixar for Non-Affine Image Warping
- VIFX uses flock animation with Prism software to create large groups of animals



CAVE

- Jim Hourihan of Santa Barbara Studios develops willy into Dynamation, which will become a part of the Wavefront software system.
- Tom Brigham and Doug Smythe and ILM get Academy Technical Achievement Award for morphing technique (MORF)
- Loren Carpenter, Rob Cook, Ed Catmull, Tom Porter, Pat Hanrahan, Tony Apodaca and Darwyn Peachey get the Academy Scientific and Engineering Award for Renderman
- Novell buys UNIX from AT&T – $150M (transfers UNIX trademark to X/Open standards organization in 1993)

1993

- February (premiere) issue of DV magazine advises “[to be able to do digital video, get] the most souped up system you can get your hands on. A fast processor (68040 on Amiga or Mac, 80486 on PC) and lots of RAM (8-64 MB) are in order. So is a large hard drive (200 MB – 1 GB) if you want to take on serious production.”
- Disk array and compression codecs allow for nonlinear editing and full motion video
- Academy Scientific and Engineering Award is given to Les Dittart, Mark Leather, Doug Smythe and

George Joblove for the development of the Digital Motion Picture Retouching System (rig removal and dirt cleanup)

- GPS system
- Adobe Acrobat
- Pat Hanrahan receives the 1993 ACM SIGGRAPH CG Achievement Award
- Ed Catmull receives the 1993 ACM SIGGRAPH Steven A. Coons Award
- Jurassic Park – ILM and Steven Spielberg
- Wavefront buys TDI
- Wired Magazine launched
- Windows NT
-
- Babylon 5 uses Amiga and Macintosh generated CGI
- Mosaic browser (NCSA)
- Xaos Tools Pandemonium image processor for the SGI
- Doom released
- Myst released (Cyan) – in 1998, it became the top selling game of all time
- Digital Domain founded by James Cameron, Stan Winston, and Scott Ross
- 1994
- SGI and Nintendo team up for Nintendo 64 product
- ILM earns Oscar for special effects for Jurassic Park



Adobe Acrobat



Myst

- Microsoft acquires Softimage – announces Windows 95
- Iomaga Zip drive
- Linux 1.0 released
- Reboot (CG cartoon) uses 3D characters (Mainframe Entertainment)
- Direct Broadcast Satellite service
- SGI founder Jim Clark resigns, forms Mosaic Communications
- Netscape browser
- VRML introduced (Mark Pesce)
- HDTV standard for transmission adopted in US
- The AMPAS Academy Award of Merit goes to Peter and Paul Vlahos for Ultimatte electronic blue screen compositing.
- Academy Scientific and Engineering Awards go to Gary Demos and Dan Cameron of III, David



Iomega Zip Drive

Difrancesco and Gary Starkweather of Pixar, and Scott Squires of ILM for pioneering work in film scanning; Lincoln Hu and Mike Mackenzie of ILM and Glenn Kennel and Mike Davis of Kodak for development work on a linear array CCD film input scanning system; and Ray Feeney, Will McCown and Bill Bishop of RFX and Les Dittert of PDI for their development work on an area array CCD film input scanning system

- Academy Technical Achievement Awards go to Mike Boudry of the Computer Film Company for pioneering work in film input scanning; and David and Lloyd Addleman for their inventions in digital image compositing.
- US Patent awarded to Pixar for creating, manipulating and displaying images
- Facetracker used by SimmGraphics to animate facial expressions for Super Mario
- Ken Torrance receives the 1994 ACM SIGGRAPH CG Achievement Award



Super Mario

1995

- Toy Story (Pixar)
- DreamWorks SKG founded (Steven Spielberg, Jeffrey Katzenberg and David Geffen)
- DreamWorks SKG and Microsoft form DreamWorks Interactive
- Internet Explorer 2.0
- amazon.com established
- Academy Scientific and Engineering Award goes to Alvy Ray Smith, Ed Catmull, Tom Porter and Tom Duff (Pixar) for pioneering inventions in digital compositing.
- Academy Technical Achievement Awards go to Gary Demos, David Ruhoff, Dan Cameron and Michelle Feraud for creation of the Digital Productions digital film compositing system; the Computer Film Company for the CFC Digital Film Compositor; and Doug Smythe, Lincoln Hu,, Doug Kay and ILM for the ILM digital film compositing system.
- US Patent awarded to Pixar for image volume data
- John Lasseter of Pixar gets Academy Award for development and application of techniques used in Toy Story
- Kurt Akeley (SGI) receives the 1995 ACM SIGGRAPH CG Achievement Award
- Jose Encarnacao receives the 1995 ACM SIGGRAPH Steven A. Coons Award
- Wavefront and Alias merge
- Pixar goes public with 6.9M share offering
- Netscape IPO ($58.25/share)

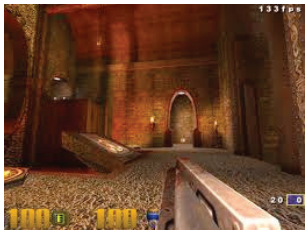
- Sony Playstation introduced
- Sun introduces Java
- Internet 2 unveiled
- MP3 standard format developed
- MSNBC debuts



Playstation

1996

- John Whitney passes away (1922-1996)
- Quake hits game market
- Macromedia buys FutureSplash Animator from FutureWave Technologies… it will become Flash.
- Marc Levoy receives the 1996 ACM SIGGRAPH CG Achievement Award
- Academy Scientific and Engineering Awards go to Jim Hourihan for particle systems in Dynamation; Brian Knep, Zoran Kacic-Alesic and Tom
- Williams of ILM for the Viewpaint 3D Paint system; and Bill Reeves for the original development and concept of particle systems.



Quake

- Academy Technical Achievement Awards go to Jim Kajiya of Cal Tech and Tim Kay for pioneering work in the creation of CGI hair and fur; Nestor Burtnyk and Marceli Wein of the National Research Center of Canada for computer assisted key framing for animation; Garth Dickie for shape-driven warping and morphing in the Elastic Reality Special Effects System; Jeff Yost, Christian Rouet, David Benson and Florian Kainz for the development of a system to create and control hair and fur in CGI; Brian Knep, Craig Hayes, Rick Sayre and Tom Williams of ILM for the creation and development of the direct input device; and Ken Perlin for the development of the Perlin Noise technique.
- Colossal Pictures files Chapter 11 bankruptcy
- Yahoo! IPO ($43/share)
- eBay launched
- SGI buys Cray Research – $764M
- SGI introduces O2 workstation
- Disney purchases DreamQuest Images; Dreamworks buys interest in PDI
- PalmPilot introduced
- Windows 95 ships



SGI O2

1997

- VIFX joins with Blue Sky
- Flash 1.0 released

- Bryce 3D
- Riven
- DVD technology unveiled
- SGI Octane
- IBM Deep Blue wins at chess
- Przemyslaw Prusinkiewicz receives the 1997 ACM SIGGRAPH CG Achievement Award
- James Foley receives the 1997 ACM SIGGRAPH Steven A. Coons Award
- Academy Scientific and Engineering Awards go to Bill Kovacs and Roy Hall for the engineering efforts that result in the Wavefront Advanced Visualizer software; Richard Shoup, Alvy Ray Smith and Tom Porter for the development of digital paint systems; John Gibson, Rob Kreiger, Milan Novacek, Glen Ozymok, and Dave Springer for the development of geometric modeling in Alias PowerAnimator; Craig Reynolds for pioneering contributions to 3D computer animation; Eben Ostby, Bill Reeves, Sam Leffler and Tom Duff for the Pixar Marionette animation system; and Dominique Boisvert, Rejean Gagne, Daniel Langlois, and Richard Lapierriere for the Actor component of the Softimage animation system.



SGI Octane

- Academy Technical Achievement Awards go to Jim Keating, Michael Wahrman and Richard Hollander for the Wavefront Advanced Visualizer software development; Greg Hermanovic, Kim Davidson, Mark Elendt and Paul Breslin for the development of PRISMS software; and Richard Chuang, Glenn Entis and Carl Rosendahl for the PDI animation system.
- Pixar interactive division dissolved
- Microsoft sued by Justice Department
- Apple Computer acquires NeXT

1998

- Titanic becomes the largest grossing motion picture in US history
- Alias Maya released
- Quicktime 3.0 released
- Google launched
- Boss Films closes
- Riven released
- Sun gets back into graphics with the Darwin Ultra series of workstations
- MPEG-4 standard announced
- XML standard
- CGI cartoon Voltron produced in US



Titanic

- SGI and Microsoft form partnership to develop APIs; SGI will develop NT-based PCs
- Geri's Game (Pixar) – awarded the Academy Award for Animated Short
- Colossal Pictures emerges from Chapter 11 bankruptcy
- Avid purchases SoftImage from Microsoft
- The SIGGRAPH Conference celebrates its 25th Anniversary in Orlando. The Siggraph 98 History Project was established to review the history to that point.



Scene from Geri's Game

- Carl Machover envisions a book that would be a compilation of significant papers in the history of CG. Edited by Rosalee Wolfe and titled *Seminal Graphics: Pioneering Efforts that Shaped the Field*, it started with a jury (Jim Blinn, Michael Cohen, Jim Foley, Don Greenberg, Machover, Stephen Spencer, and Turner Whitted) to select the "seminal" papers that would be included. The book was published in December.
- Jim Blinn delivers the SIGGRAPH 98 Keynote address
- Michael Cohen (Microsoft) receives the 1998 ACM SIGGRAPH CG Achievement Award
- Maxine Brown receives the first SIGGRAPH Outstanding Service Award
- Academy Technical Achievement Awards go to Doug Roble (Digital Domain) and Thad Beier (Hammerhead) for Tracking Technology; Nick Foster (PDI) for water simulation systems; David Difrancesco, Bala Manian and Tom Noggle for laser film recording and Cary Philips for the ILM Caricature animation system
- Academy Scientific and Engineering Awards go to Gary Tregaski for the primary design and Dominique Boisvert, Philipe Panzini and Andre Leblanc for the development of the Flame and Inferno software; Roy Ference, Steve Schmidt, Richard Federico, Rockwell Yarid and Mike McCrackan for the design and development of the Kodak Lightning laser recorder.

1999

- The graphics world loses David Evans at age 74
- Bunny (Chris Wedge – Blue Sky) – awarded the Academy Award for Animated Short
- Star Wars Episode One – The Phantom Menace uses 66 digital characters composited with live action
- VIFX and Rhythm & Hues merge
- The graphics world loses Pierre Bezier
- Silicon Graphics Incorporated changes its name to SGI
- Fred Brooks receives the Turing Award
- NewTek ports Toaster to NT
- melissa computer virus



Scene from Bunny

- SIGGRAPH celebrates its 30th Anniversary as an organization at SIGGRAPH 99 in Los Angeles
- Tony DeRose (Pixar) receives the 1999 ACM SIGGRAPH CG Achievement Award
- Jim Blinn receives the 1999 ACM SIGGRAPH Steven A. Coons Award
- SGI cuts Cray, NT production and High end graphic design
- Side Effects Houdini ported to Linux
- Napster created
- Toy Story 2 produced by Pixar
- Stuart Little produced by Sony Pictures Imageworks
- Fantasia 2000 produced by Disney
- Disney's DreamQuest and Feature Animation join to form The Secret Lab (TSL)



Stuart Little

2000s

2000

- Playstation 2
- SGI sells Cray to Tera Computer
- Human genome mapped by Celera
- Microsoft X-Box prototype shown at SIGGRAPH 2000
- Dinosaur produced by Disney
- The graphics world loses Phil Mittleman (MAGI)
- Walking with Dinosaurs – Framestore (UK)
- Mission to Mars effects produced by ILM and The Secret Lab
- Academy of Motion Pictures Arts and Sciences Award of Merit awarded to Rob Cook, Loren Carpenter and Ed Catmull for the significant advancements to the field of motion picture rendering as exemplified in Pixar's Renderman



Dinosaur

- Academy Technical Achievement Awards go to Venkat Krishnamurthy for the Paraform software for digital form development; and George Burshukov, Kim Libreri and Dan Piponi for image based rendering
- SIGGRAPH 2000 held in New Orleans
- Tom DeFanti and Copper Giloth receive the 2000 SIGGRAPH Outstanding Service Award
- David Salesin receives the 2000 ACM SIGGRAPH CG Achievement Award

- Hollow Man produced by Sony Pictures Imageworks
- How the Grinch Stole Christmas (Centropolis)
- Maya ported to Macintosh
- Mac OS-X introduced



Hollowman

2001

- SIGGRAPH 2001 held in Los Angeles
- Lance Williams receives the 2001 ACM SIGGRAPH Steven A. Coons Award
- Andrew Witkin receives the 2001 ACM SIGGRAPH CG Achievement Award
- Paul Debevec receives the 2001 ACM SIGGRAPH Significant New Researcher Award
- The graphics world loses Bob Abel (Sept 23)
- Disney's Secret Lab closes
- Apple iPod
- Side Effects Houdini ported to Sun
- AOL/TimeWarner merger
- Autodesk acquires Media100 software product line
- Advanced Audio Coding (AAC) format introduced by Dolby Labs and Fraunhofer Institute
- Windows XP



iPod

- Academy Technical Achievement Awards go to Garland Stern for the Cel Paint software system; Uwe Sassenberg and Rolf Schneider for the 3D Equalizer matchmove system; Lance Williams for pioneering influence in animation and effects; Bill Spitzak, Paul Van Camp, Jonathan Egstad and Price Pethal for the NUKE-2D compositing software; Steve Sullivan and Eric Shafer for the ILM Motion and Structure Recovery System (MARS); and John Anderson, Jim Hourihan, Cary Philips and Sebastion Marino for the ILM Creature Dynamics System
- The Academy of Motion Pictures Arts and Sciences approve a new category for the Oscars titled Best Animated Feature Film Award. Nine films were declared eligible: Final Fantasy: The Spirits Within, Jimmy Neutron: Boy Genius, Marco Polo: Return to Xanadu, Monsters, Inc., Osmosis Jones, The Prince of Light, Shrek, The Trumpet of the Swan, and Waking Life.
- Significant FX movies – Final Fantasy (Square), Monsters Inc.(Pixar), Harry Potter, A.I., Lord of the Rings, Shrek (PDI), The Mummy Returns (ILM), Tomb Raider (Cinesite), Jurassic Park III, Pearl Harbor (ILM), Planet of the Apes (Asylum)

- Microsoft xBox and Nintendo Gamecube released



xBox

2002

- SIGGRAPH 2002 held in San Antonio, Texas
- Bert Hertzog (Fraunhofer Center for Research in Computer Graphics) receives the 2002 Outstanding Service Award for extraordinary service to ACM SIGGRAPH by a volunteer
- David Kirk (NVIDIA) receives the 2002 ACM SIGGRAPH CG Achievement Award
- HP / Compaq merger
- William Fetter (Boeing) passes away.
- Steven Gortler (Harvard Univ) receives the 2002 ACM SIGGRAPH Significant New Researcher Award
- Alias|Wavefront, an SGI company, was awarded an Academy Award of Merit Oscar at the Scientific and Technical Awards ceremony of the Academy of Motion Picture Arts and Sciences for its development of Maya software.
- Mark Elendt, Paul Breslin, Greg Hermanovic and Kim Davidson receive a Scientific and Engineering Award for their continued development of the procedural modeling and animation components of their Prisms program, as exemplified in the Houdini software package.
- Academy Technical Achievement Awards ?To Dick Walsh for the development of the PDI/ Dreamworks Facial Animation System. ?To Thomas Driemeyer and to the mathematicians, physicists and software engineers of Mental Images for their contributions to the Mental Ray rendering software for motion pictures. ?To Eric Daniels ,George Katanics ,Tasso Lappas and Chris Springfield for the development of the Deep Canvas rendering software.

2003

- Atari Games Corporation (Midway Games West) out of business.
- Oscar nominees for Best animated short film: The Cathedral, Platige Image, Tomek Baginski; The Chubb Chubbs!, Sony Pictures Imageworks,Eric Armstrong; Das Rad, Filmakademie Baden-Württemberg GmbH, Chris Stenner and Heidi Wittlinger; Mike's New Car, Pixar Animation Studios,Pete Docter and Roger Gould; Mt. Head, Yamamura Animation Production, Koji Yamamura; for Achievement in visual effects: The Lord of the Rings: The Two Towers, Jim Rygiel, Joe Letteri, Randall William Cook and Alex Funke; Spider-Man, John Dykstra, Scott Stokdyk, Anthony LaMolinara and John Frazier, Star Wars Episode II: Attack of the Clones, Rob Coleman, Pablo Helman, John Knoll and Ben Snow;Ice Age nominated for Best Animated Feature Film
- Dolby Labs acquires DemoGraFX, Gary Demos' company
- SIGGRAPH 2003 held in San Diego
- David Brown (founder – Blue Sky and ex of MAGI) passes away

- Pat Hanrahan (Stanford) receives the 2003 ACM SIGGRAPH Steven A. Coons Award
- Peter Schrøder (Cal Tech) receives the 2003 ACM SIGGRAPH CG Achievement Award
- Mathieu Desbrun (USC) receives the 2003 ACM SIGGRAPH Significant New Researcher Award
- The Cathedral selected as Best Short Film in SIGGRAPH Electronic Theatre
- Apple introduces the Power Mac G5
- Alias/Wavefront becomes Alias



PowerMac G5

2004

- Jim Clark elected to Fellow in Academy of Arts and Sciences
- Oscar nominees for Best animated short film: Harvie Krumpet – Adam Elliot; Boundin' – Bud Luckey; Destino – Dominique Monfery, Roy Edward Disney; Gone Nutty – Carlos Saldanha, John C. Donkin; Nibbles – Christopher Hinton; for Best animated feature : Finding Nemo – Andrew Stanton; Brother Bear – Aaron Blaise, Robert Walker; Triplettes de Belleville, Les – Sylvain Chomet; for Achievement in Visual Effects: Lord of the Rings: The Return of the King – Jim Rygiel, Joe Letteri, Randall William Cook, Alex Funke; Master and Commander: The Far Side of the World – Daniel Sudick, Stefen Fangmeier, Nathan McGuinness, Robert Stromberg; Pirates of the Caribbean: The Curse of the Black Pearl – John Knoll, Hal T. Hickel, Charles Gibson, Terry D. Frazee
- Academy Scientific and Engineering Awards go to Stephen Regelous for the design and development of Massive, the autonomous agent animation system used for the battle sequences in "The Lord of the Rings" trilogy. Academy Technical Achievement Awards go to Christophe Hery, Ken McGaugh, and Joe Letteri for their groundbreaking implementations of practical methods for rendering skin and other translucent materials using subsurface scattering techniques; Henrik Wann Jensen, Stephen R. Marschner, and Pat Hanrahan for their pioneering research in simulating subsurface scattering of light in translucent materials as presented in their paper "A Practical Model for Subsurface Light Transport."
- SIGGRAPH 2004 held in Los Angeles
- Steve Cunningham and Judith Brown receive the 2004 Outstanding Service Award for extraordinary service to ACM SIGGRAPH by a volunteer
  Hugues Hoppe (Microsoft) receives the 2004 ACM SIGGRAPH CG Achievement Award
- Zoran Popovic (Univ. Washington) receives the 2004 ACM SIGGRAPH Significant New Researcher Award
- Chris Landreth's Ryan selected for Jury Award in SIGGRAPH Electronic Theatre; Sejong Park's Birthday Boy selected Best Animated Short
- Ub Iwerks Award given to Ed Catmull for creative work at Pixar
- Alias acquired from SGI by Accel-KKR and the Ontario Teachers' Pension Plan.



Ryan

2005

- Oscar nominees for Best animated short film: Sejong Park & Andrew Gegory – Birthday Boy; Jeff Fowler & Tim Miller – Gopher Broke; Bill Plympton – Guard Dog; Mike Gabriel & Baker Bloodworth – Lorenzo; Chris Landreth – Ryan; for Best animated feature : Brad Bird – The Incredibles; Bill Damasschka – Shark Tale; Andrew Adamson – Shrek 2; for Achievement in Visual Effects: Roger Guyett, Tim Burke, John Richardson and Bill George – Harry Potter and the Prisoner of Azkaban; John Nelson, Andrew R. Jones, Erik Nash and Joe Letteri – I, Robot; John Dykstra, Scott Stokdyk, Anthony LaMolinara and John Frazier – Spider-Man 2
- Academy Scientific and Technical Awards go to Dr. Julian Morris, Michael Birch, Dr. Paul Smyth and Paul Tate for the development of the Vicon motion capture technology; Dr. John O. B. Greaves, Ned Phipps, Antonie J. van den Bogert and William Hayes for the development of the Motion Analysis motion capture technology; Dr. Nels Madsen, Vaughn Cato, Matthew Madden and Bill Lorton for the development of the Giant Studios motion capture technology; Alan Kapler for the design and development of Storm , a software toolkit for artistic control of volumetric effects.
- SIGGRAPH 2005 held in Los Angeles
    - Steve Cunningham and Judith Brown receive the 2004 Outstanding Service Award for extraordinary service to ACM SIGGRAPH by a volunteer
      Tomoyuki Nishita (Tokyo University) receives the 2005 ACM SIGGRAPH Steven Anson Coons Award
    - Jos Stam (Alias) receives the 2005 ACM SIGGRAPH CG Achievement Award
    - Ron Fedkiw (Stanford) receives the 2005 ACM SIGGRAPH Significant New Researcher Award
    - Shane Acker's 9 selected for Best of Show in SIGGRAPH Electronic Theatre; Fallen Art and La Migration Bigoudenn selected for Jury Honors
- Adobe purchases Macromedia for US$3.4B.

2006

- Oscar nominees for Best animated short film: "Badgered" – A National Film and Television School Production, Sharon Colman; "The Moon and the Son: An Imagined Conversation" – A John Canemaker Production, John Canemaker and Peggy Stern; "The Mysterious Geographic Explorations of Jasper Morello" (Monster Distributes) – A 3D Films Production, Anthony Lucas; "9" – A Shane Acker Production, Shane Acker; "One Man Band" – A Pixar Animation Studios Production, Andrew Jimenez and Mark Andrews. for Best animated feature : "Howl's Moving Castle" (Buena Vista) – Hayao Miyazaki; "Tim Burton's Corpse Bride" (Warner Bros.) – Mike Johnson and Tim Burton; "Wallace & Gromit in the Curse of the Were-Rabbit" (DreamWorks Animation SKG) – Nick Park and Steve Box. for Achievement in Visual Effects: "The Chronicles of Narnia: The Lion, the Witch and the Wardrobe" (Buena Vista) – Dean Wright, Bill Westenhofer, Jim Berney and Scott Farrar; "King Kong" (Universal) – Joe Letteri, Brian Van't Hul, Christian Rivers and Richard Taylor; "War of the Worlds" (Paramount and DreamWorks) – Dennis Muren, Pablo Helman, Randal M. Dutra and Daniel Sudick

- Academy Scientific and Technical Awards go to David Baraff, Michael Kass and Andrew Witkin for their pioneering work in physically-based computer-generated techniques used to simulate realistic cloth in motion pictures.; to John Platt and Demetri Terzopoulos for their pioneering work in physically-based computer-generated techniques used to simulate realistic cloth in motion pictures; to Ed Catmull, for the original concept, and Tony DeRose and Jos Stam for their scientific and practical implementation of subdivision surfaces as a modeling technique in motion picture production. Gary Demos was honored with the 19th Gordon E. Sawyer Award, presented to an individual in the motion picture industry whose technological contributions have brought credit to the industry.
- Disney acquires Pixar for $7.4B; Ed Catmull named President; Steve Jobs joins Disney Board
- Apple Computer adopts the Intel chip, introduces Bootcamp to run Windows.
- SGI files Chapter 11 protection
- Richard “Doc” Bailey, the “Jimi Hendrix of CG” passes away
- Michael Bay and Wyndcrest Holdings buy Digital Domain, replace Scott Ross
- SIGGRAPH 2006 held in Boston. SIGGRAPH awards are as follows:
    - Computer Graphics Achievement Award Thomas W. Sederberg, Brigham Young University
    - Significant New Researcher Award Takeo Igarashi, The University of Tokyo
    - ACM SIGGRAPH Outstanding Service Award John M. Fujii, Hewlett Packard Company
    - One Rat Short – Best of Show, Computer Animation Festival Alex Weil, Charlex Inc.
- CGI pioneer Bill Kovacs passes away.
- AMD purchases ATI Technologies for $5.4B
- Autodesk acquires Alias for US$197M.

2007

- SIGGRAPH 2007 held in San Diego. SIGGRAPH awards are as follows:
    - Computer Graphics Achievement Award – Greg Ward (Radiance)
    - Significant New Researcher Award – Ravi Ramamoorthi
    - Steven Coons Award – Nelson Max
    - Ark – Best of Show, Computer Animation Festival; Dreammaker – Jury Honors; En Tus Brazos – Award of Excellence
- Academy Award nominations for Animated feature: Ratatouille (Disney/Pixar) – Brad Bird, Persepolis (Sony Pictures Classics) – Marjane Satrapi and Vincent Paronnaud, Surf’s Up (Columbia/Sony Pictures Animation) – Ash Brannon and Chris Buck. For Animated Short: Peter & the Wolf – Se-ma-for, BreakThru Films – Suzie Templeton, Even Pigeons Go To Heaven – BUF – Samuel Tourneux and Simon Vanesse, I Met the Walrus – Josh Raskin, Madame Tutli-Putli – National Film Board of Canada – Chris Lavis and Maciek Szczerbowski, My Love – Aleksandr Petrov. For Visual Effects: The Golden Compass – Michael

Fink, Bill Westenhofer, Ben Morris, and Trevor Wood, Pirates of the Caribbean: At World's End – John Knoll, Hal Hickel, Charles Gibson, and John Frazier, Transformers – Scott Farrar, Scott Benza, Russell Earl, and John Frazier.

2008

- SIGGRAPH 2008 held in Los Angeles. SIGGRAPH awards are as follows:
    - Computer Graphics Achievement Award – Ken Perlin
    - Significant New Researcher Award – Maneesh Agrawala
    - ACM SIGGRAPH Outstanding Service Award – Stephen Spencer, University of Washington
    - Oktapodi – Best of Show; 893 – Best Student Piece; Mauvais Role – Jury Award; Our Wonderful Nature – Best Told Fable; Oktapodi – Audience Prize Computer Animation Festival
- Academy Award nominations for Animated feature: WALL-E (Disney/Pixar) – Andrew Stanton, Bolt (Disney) – Chris Williams and Byron Howard, Kung Fu Panda (DreamWorks/Pacific Data Images) – John Wayne Stevenson and Mark Osborne. For Animated Short: La Maison en petits cubes – Robot & Oh! Production – Kunio Katō, Lavatory – Lovestory – Melnitsa Animation Studio – Konstantin Bronzit, Oktapodi – Gobelins L'Ecole de L'Image – Emud Mokhberi and Thierry Marchand, Presto – Pixar – Doug Sweetland, This Way Up – Nexus Productions – Alan Smith and Adam Foulkes. For Visual Effects: The Curious Case of Benjamin Button – Eric Barba, Steve Preeg, Burt Dalton, and Craig Barron, The Dark Knight – Nick Davis, Chris Corbould, Tim Webber, and Paul Franklin, Iron Man – John Nelson, Ben Snow, Dan Sudick, and Shane Mahan

2009

- SIGGRAPH 2009 held in New Orleans. SIGGRAPH awards are as follows:
    - Computer Graphics Achievement Award – Michael Kass
    - Significant New Researcher Award – Wojciech Matusik
    - Stephen A. Coons Award – Robert Cook
    - Distinguished Artist Award for Lifetime Achievement in Digital Art – Lynne Hershman Leeson, Roman Verostko
    - French Roast – Best of Show; Project: Alpha – Best Student Piece; Dix – Jury Award; Unbelievable Four – Best Told Fable, Computer Animation Festival
- Academy Award nominations for Animated feature: Up (Disney/Pixar) – Pete Docter, Coraline (Focus Features/LAIKA) – Henry Selick, Fantastic Mr. Fox (20th Century Fox/Regency) – Wes Anderson, The Princess and the Frog (Disney) – John Musker and Ron Clements, The Secret of Kells (Cartoon Saloon) – Tomm Moore and Nora Twomey. For Animated Short: Logorama – H5, Autour de Minuit Productions – Nicolas Schmerkin, Granny O'Grimm's Sleeping Beauty – Brown Bag Films – Nicky Phelan and Darragh O'Connell, French Roast – Fabrice Joubert, The Lady and the Reaper – Kandor Graphics – Javier Recio

Gracia, A Matter of Loaf and Death – Aardman Animations – Nick Park. For Visual Effects: Avatar – Joe Letteri, Stephen Rosenbaum, Richard Baneham, and Andrew R. Jones, District 9 – Dan Kaufman, Peter Muyzers, Robert Habros, and Matt Aitken, Star Trek – Roger Guyett, Russell Earl, Paul Kavanagh, and Burt Dalton

- Significant animated movies: 9 (USA), A Christmas Carol (USA), Afro Samurai: Resurrection (USA and Japan), Alvin and the Chipmunks: The Squeakquel (USA), Astro Boy (USA and Japan), Cloudy with a Chance of Meatballs (USA), Coraline (USA), Fantastic Mr. Fox (USA), Garfield's Pet Force (USA and South Korea), Ice Age 3: Dawn of the Dinosaurs (USA), Monsters vs. Aliens (USA), Up (USA)

2010

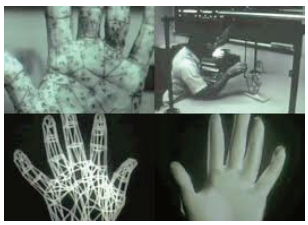
- SIGGRAPH 2010 held in Los Angeles. SIGGRAPH awards are as follows:
    - Computer Graphics Achievement Award Jessica Hodgins
    - Significant New Researcher Award – Alexei Efros
    - ACM SIGGRAPH Outstanding Service Award Kellogg S. Booth
    - Distinguished Artist Award for Lifetime Achievement in Digital Art – Yoichiro Kawaguchi
    - Loom – Best of Show; Best Student Piece – The Wonder Hospital; Jury Award – Poppy, Computer Animation Festival
- Academy Award nominations for Animated feature: Toy Story 3 (Disney/Pixar) – Lee Unkrich, How to Train Your Dragon (DreamWorks/Pacific Data Images) – Chris Sanders and Dean DeBlois, The Illusionist (Pathé Pictures/Sony Pictures Classics) – Sylvain Chomet. For Animated Short: The Lost Thing – Shaun Tan and Andrew Ruhemann, Day & Night – Pixar – Teddy Newton, The Gruffalo – Magic Light Pictures, Studio Soi – Jakob Schuh and Max Lang, Let's Pollute – Geefwee Boedoe, Madagascar, a Journey Diary – Bastien Dubois.
- For Visual Effects: Inception – Paul Franklin, Chris Corbould, Andrew Lockley and Peter Bebb, Alice in Wonderland – Ken Ralston, David Schaub, Carey Villegas and Sean Phillips, Harry Potter and the Deathly Hallows: Part 1 – Tim Burke, John Richardson, Christian Manz and Nicolas Aithadi, Hereafter – Michael Owens, Bryan Grill, Stephan Trojanski and Joe Farrell, Iron Man 2 – Janek Sirrs, Ben Snow, Ged Wright and Daniel Sudick
- Significant animated movies: Alpha and Omega (USA), Despicable Me (USA), MegaMind (USA), Shrek Forever After (USA), Tangled (USA), Tinker Bell And The Great Fairy Rescue (USA), Toy Story 3 (USA).

2011

- SIGGRAPH 2011 held in Vancouver. SIGGRAPH awards are as follows:
    - Computer Graphics Achievement Award – Richard Szeliski
    - Significant New Researcher Award – Olga Sorkine
    - Stephen A. Coons Award – Jim Kajiya

  - Distinguished Artist Award for Lifetime Achievement in Digital Art – Charles Csuri
  - The Fantastic Flying Books of Mr. Morris Lessmore – Best of Show; Flamingo Pride – Best Student Piece; Paths of Hate – Jury Award, Computer Animation Festival

- Academy Award nominations for Animated feature: Rango (Paramount Pictures/Nickelodeon Movies/Blind Wink/GK Films) – Gore Verbinski, A Cat in Paris (Folimage with Digit Anima, France 3 Cinéma, Lumière, Lunanime, Radio Télévision Belge Francophone) – Alain Gagnol and Jean-Loup Felicioli, Chico & Rita (Isle of Man Film/Magic Light Pictures/Disney/CinemaNX) – Fernando Trueba and Javier Mariscal, Kung Fu Panda 2 (DreamWorks Animation/Paramount Pictures) – Jennifer Yuh Nelson, Puss in Boots (DreamWorks Animation/Paramount Pictures) – Chris Miller.
- For Animated Short: The Fantastic Flying Books of Mr. Morris Lessmore – Moonbot Studios – William Joyce and Brandon Oldenburg, Dimanche – National Film Board of Canada – Patrick Doyon, La Luna – Pixar – Enrico Casarosa, A Morning Stroll – Studio AKA – Grant Orchard and Sue Goffe, Wild Life – National Film Board of Canada – Wendy Tilby and Amanda Forbis.
- For Visual Effects: Hugo – Rob Legato, Joss Williams, Ben Grossmann and Alex Henning, Harry Potter and the Deathly Hallows: Part 2 – Tim Burke, David Vickery, Greg Butler, and John Richardson, Real Steel – Erik Nash, John Rosengrant, Danny Gordon Taylor, and Swen Gillberg, Rise of the Planet of the Apes – Joe Letteri, Dan Lemmon, R. Christopher White, and Daniel Barrett, Transformers: Dark of the Moon – Scott Farrar, Scott Benza, Matthew E. Butler, and John Frazier
- Significant animated movies: Arthur Christmas (USA), Cars 2 (USA), Gnomeo and Juliet (USA/UK), Happy Feet 2 (USA/Australia), Hop (USA), Kung Fu Panda 2 (USA), Puss in Boots (USA), Rango (USA, Rio (Brazil and USA), The Adventures of Tintin: Secret of the Unicorn (USA, The Smurfs (USA).
- Ed Catmull's CG Hand added to National Film Registry



Catmull's Hand

2012

- Carl Machover, computer graphics pioneer and graphics "evangelist", dies at 84.
- Buzz Potamkin, legendary animation producer ("I Want My MTV") and head of Buzzco Productions dies at 66.
- Digital Domain files for Chapter 11 and closes all Florida studios; emerges from bankruptcy after selling to Galloping Horse America, a division of a Beijing media company, and Reliance MediaWorks, part of the Indian conglomerate Reliance Group in late September for $30.2M
- SIGGRAPH 2012 held in Los Angeles. SIGGRAPH awards are as follows:
  - Computer Graphics Achievement Award – Greg Turk
  - Significant New Researcher Award – Karen Liu
  - Outstanding Service Award – David Kasik
  - Distinguished Artist Award for Lifetime Achievement in Digital Art – Jean-Pierre Hébert
  - Réflexion – Best in Show; Estefan – Best Student Piece; How To Eat Your Apple – Jury Award,,

Rosette – Well Told Fable Award – Computer Animation Festival

2013

- Rhythm and Hues files for bankruptcy (February) – Purchased by Prana Studios (April)
- SIGGRAPH 2013 held in Anaheim. SIGGRAPH awards are as follows:
    - Computer Graphics Achievement Award – Holly Rushmeier
    - Steven Anson Coons Award – Turner Whitted
    - Significant New Researcher Award – Niloy Mitra
    - Distinguished Artist Award for Lifetime Achievement in Digital Art – Manfred Mohr
    - Outstanding Service Award – Mary Whitton
    - À la Française – Best in Show; Rollin' Safari – Best Student Piece; Lost Senses – Jury Award, – Computer Animation Festival

Other Related Historical Links

Other related historical links

- Computer Graphics World 25th Anniversary Retrospectives
    - *Part 1 – Digital Art*
    - *Part 2 – CAD/CAM/CAE*
    - *Part 3 – Gaming*
    - *Part 4 – Broadcast*
    - *Part 5 – Science*
    - *Part 6 – Architecture*
    - *Part 7 – Movies*
- *http://eriq.lecture.ub.ac.id/files/2010/04/CG-Timelines-artof3d.pdf* (Timelines and Milestones of Computer Animation and Visual Effects, from The Art of Computer Animation and Imaging (Kerlow)
- *http://www.oscars.org/oscars/awards-databases-0* (AMPAS Visual Effects Awards Database)
- *https://www.timetoast.com/timelines/media-timeline-most-important-inventions-in-media-history/* (History of media)
- *https://arstechnica.com/gadgets/2013/06/the-future-of-tv-a-star-is-born/* (History of Television Broadcast)
- *http://aleph0.clarku.edu/~djoyce/mathhist/* (History of mathematics)
- *http://www.xnumber.com/xnumber/Microcomputer_invention.htm*(History of microcomputers)
- *http://ei.cs.vt.edu/~history/* (History of computing)
- *http://www.computerhistory.org/* (Computer History Museum)
- *http://www.virtualaltair.com/virtualaltair.com/vac_history.asp* (History of the Microcomputer Revolution)
- *http://www.apple-history.com/* (History of Apple Computer)
- *http://apple2history.org/* (History of the Apple II)
- *http://www.xnumber.com/xnumber/Microcomputer_invention.htm* (History of the development of the Macintosh)

- *http://www.timetoast.com/timelines/77845* (ITGS history page)
- *http://joelorr.squarespace.com/community-caddcam-history-proj/* (Joel Orr's Community History of CADD and PLM)
- *http://pctimeline.info/workstation/*(History of the Workstation)
- *http://www.nobelprize.org/educational/physics/integrated_circuit/history/http://www.nobelprize.org/educational/physics/integrated_circuit/history/* (Integrated Circuit History)
- *http://www.lifesmith.com/history.html* (History of Fractals)
- *http://www.inwap.com/mf/reboot/alliance/1980s.txt* (Taken from "On Becoming an Animator" (Miller))
- *http://www.awn.com/mag/issue2.5/2.5pages/2.5collinssiggraph.html* (Joan Collins article from 8/97 AWN)
- *http://thinkquest.org/pls/html/think.library* (ThinkQuest History page)
- *http://www.amazon.com/Computer-Animation-Second-Algorithms-Techniques/dp/0125320000/ref=dp_ob_title_bk?ie=UTF8&qid=998169184&sr=1-39*(Rick Parent's book on Computer Animation)
- *http://www.internetvalley.com/intval1.html* (History of the Internet) *http://www.vtoldboys.com/editingmuseum/index.htm* (Museum of Video Editing)
- *http://dam.org/home*(Digital Art Museum history site)
- *AMPAS Scientific and Technical Awards in Digital Effects* (from the AMPAS Awards database)

Corporate historical links

- *http://www.lucasfilm.com/inside/history/* (Timeline of Lucasfilm history)
- *http://www.motorolasolutions.com/US-EN/About/Company+Overview/History/Timeline* (Motorola timeline)
- *http://www.bbn.com/timeline/* (BBN and internet timeline)
- *http://www.synthespianstudios.com/about/* (Kleiser/Walczak history)
- *http://www.rga.com/about/*(R. Greenberg History)
- *http://timelineindex.com/content/view/1087* (Microsoft timeline)
- *http://www.hp.com/hpinfo/abouthp/histnfacts/museum/* (HP Virtual Museum)
- *http://www.ampex.com/ampex-history/* (Ampex Corporation history)
- *http://www.visualeffectssociety.com*/ Visual Effects Society

Other Visual Effects Resources

- *http://www.vfxhq.com/* (Visual Effects Headquarters)
- *https://wmavity.wordpress.com/2017/01/21/a-history-of-visual-effects-oscar-shortlists-and-bake-offs/*(History of Special Effects [at the Oscars] (Intl Cinematographers Guild))
- *http://www.cinefex.com/* (Cinefex magazine)

Video Games

- *http://www.landley.net/history/mirror/atari/museum/Atari-Timeline.html* (History of Atari)
- *http://www.movingimage.us/files/exhibitions/minisites/computerspace98/index2.html*(American Museum of the Moving Image Computer Space 98 video game exhibition)
- *http://www.lysator.liu.se/adventure/* (a site dedicated to a listing of adventure games (interactive fiction))

List of Movies and Videos and Image Galleries

Movies and Videos (External and Embedded)

Number	Title	URL
Intro	History of CG	HistoryCG-1.m4v
1.1	Simulation of a Vacuum Tube	monkeysVIDEO_T1-1.m4v
2.1	On Guard! – 1956	http://www.youtube.com/watch?v=Kpahs3MAEDc
2.2	John Whitney Animation Flipbook	http://www.youtube.com/watch?v=_cmrTxtlgLA
2.3	Computers: Challenging Man's Supremacy – John Whitney Interview (1976)	https://www.youtube.com/watch?v=5eMSPtm6u5Y
2.4	Screening Room Interview with John Whitney	JohnWhitneyInterview_med.m4v
2.5	Interview with John Whitney	https://www.youtube.com/watch?v=pGH5aCYtjeE
2.6	Whitney Catalog (1961)	https://www.youtube.com/watch?v=TbV7loKp69s
2.7	Arabesque (John Whitney)	Arabesque_1963_med.m4v
2.8	Lapis – James Whitney (1966)	http://www.youtube.com/watch?v=kzniaKxMr2g
2.9	Permutations (1966)	http://www.youtube.com/watch?v=BzB31mD4NmA
2.10	Matrix III (1972)	http://www.youtube.com/watch?v=ZrKgyY5aDvA
3.1	Alan Kay – Video of Sketchpad	alankay-on-sketchpad-1987.m4v
3.2	Original Sketchpad Demo – Excerpt	https://www.youtube.com/watch?v=57wj8diYpgY
3.3	General Motors DAC-1 Demo	DAC-1demo-1.m4v
4.1	Generalized Coons' Surface	https://www.youtube.com/watch?v=5Jc007b0CaU
4.2	Scenes from The Artist and The Computer	
4.3	Two Gyro Gravity Gradient Altitude Control System	https://www.youtube.com/watch?v=m8Rbl7JG4Ng
4.4	Incredible Machine	http://techchannel.att.com/play-video.cfm/2012/6/14/AT&T-Archives-Incredible-Machine-Bonus-Edition
4.5	A Computer Technique for the Animation of Movies	http://techchannel.att.com/play-video.cfm/2012/9/10/AT&T-Archives-Computer-Technique-Production-Animated-Movies
4.6	PoemField No. 2 (1966)	http://techchannel.att.com/play-video.cfm/2012/8/13/AT&T-Archives-
4.7	Force, Mass and Motion	http://techchannel.att.com/play-video.cfm/2012/8/20/AT&T-Archives-
4.8	Hypercube/4D Hypermovie	http://techchannel.att.com/play-video.cfm/2012/8/17/AT&T-Archives-
4.9	Carla's Island – 1981	https://www.youtube.com/watch?v=kO-JB1WHmRc
4.10	DNA with Ethidium (1978)	http://www.youtube.com/watch?v=TD0-2lkvfgU
4.11	Intercalation of Doxorubicin with DNA (1980)	http://www.youtube.com/watch?v=pCVsJ-maSa8
4.12	Halftone Animation (1972)	HandFace_1972.m4v
4.13	Pong Man (Van Hook)	pongman_77.m4v
4.14	Dawn of an Epoch (OSU)	epochd-1.m4v
4.15	Form•Z 2007 User Reel	https://www.youtube.com/watch?v=3PewiPQdA5g

Number	Title	URL
4.16	Hummingbird (1966)	http://www.youtube.com/watch?v=awvQp1TdBqc
4.17	Rigid Body Dynamics	http://www.youtube.com/watch?v=AmFYMbJ0Eew
4.18	PM Magazine	http://www.youtube.com/watch?v=-4b2DsTEXag
4.19	Interacting Galaxies	http://excelsior.biosci.ohio-state.edu/~carlson/history/moovees/galaxie
4.20	Anima II	http://www.youtube.com/watch?v=Sknwhx0aUbo
4.21	The Circus	http://www.youtube.com/watch?v=u1z9Q4tU2a8
4.22	Procedural Terrain Models	http://www.youtube.com/watch?v=Qy-kyqU7J9I
4.23	Snoot and Muttly	http://www.youtube.com/watch?v=3RlrtAf7Qsg
4.24	Broken Heart	http://www.youtube.com/watch?v=iPLFB6_xpAI
4.25	Tuber's Two Step	http://www.youtube.com/watch?v=k-GZ0PogVLw
4.26	Zeltzer SAS V1	http://excelsior.biosci.ohio-state.edu/~carlson/history/moovees/SAS.m
4.27	Euhrthmy Motion Studies	http://www.youtube.com/watch?v=qVcyttQbKP0
4.28	Euhrythmy	http://www.youtube.com/watch?v=HLiD2yCBY8o
4.29	Coredump	http://www.youtube.com/watch?v=4CcJx0_b3mo
4.30	Tectonic Evolution	http://www.youtube.com/watch?v=92ZTkMQe0q4
4.31	Mechanical Universe Excerpts	Em
4.32	LA – The Movie (1987)	http://www.youtube.com/watch?v=6RsXCbpJG54
4.33	Mars – The Movie (1989)	http://www.youtube.com/watch?v=vMjlD6h2qko
4.34	Voyager 2 Flyby of Saturn (1981)	https://www.youtube.com/watch?v=SQk7AFe13CY
4.35	Evolution (1980) – from Cosmos	https://www.youtube.com/watch?v=YEdm1GoUo-o
4.36	Pioneer 11 Encounters Saturn (1980)	https://www.youtube.com/watch?v=myYIKJF589g
4.37	Voyager 2 Encounters Jupiter (1978)	https://www.youtube.com/watch?v=o4xIJlEV8Kw
4.38	Project Mathematics! (1988)	https://www.youtube.com/watch?v=PslowEd4-68
4.39	Voyager 2 Flyby of Uranus (1986)	https://www.youtube.com/watch?v=DrKQaDupdWQ
4.40	Computer Visions feature on Jim Blinn (1991)	https://www.youtube.com/watch?v=ePZ301Sg4HI&t=6s
4.41	Excerpt from Hunger/LaFaim	hunger-excerpt.m4v
5.1	Cornell In Perspective	Em
5.2	Sunstone (1979)	https://www.youtube.com/watch?v=tMW15OajuKc
5.3	Excerpt from The Works (NYIT)	works.m4v
5.4	The Works – 1984	http://www.youtube.com/watch?v=18OSLeWJVJQ
5.5	Kraftwerk Musique	http://www.dailymotion.com/video/x175jh_kraftwerk-music-non-stop_
5.6	JCGL Demo Reel 1983	https://www.youtube.com/watch?v=_WlAnrdtGmg
5.7	Pixel Planes (NCSU)	https://www.youtube.com/watch?v=7mzpZ861wEw
5.8	Sorting Out Sorting	https://www.youtube.com/watch?v=gv0JUEqaAXo
5.9	NC State Graphics (c1973)	https://www.youtube.com/watch?v=4MHzU4xJ4pk

Number	Title	URL
	EVL – Electronic Visualization Event	https://www.youtube.com/watch?v=pNJ-f-hqAWI
6.1	Digital Effects 1985 Demo	https://www.youtube.com/watch?v=Mv78UsrZ07g
6.2	Where the Wild Things Are Test	Em
6.3	MAGI Demo – 1980	magi_80-1.m4v
6.4	MAGI Demo – 1982	https://www.youtube.com/watch?v=WxetroPVCl0
6.5	MAGI Demo – 1984	https://www.youtube.com/watch?v=Ivk_LPQP6Ag
6.6	First Flight	https://www.youtube.com/watch?v=EQZO1-4D0lg
6.7	Triple-I Demo – excerpt	tripli-i-excerpt.m4v
6.8	The Little Death (Elson)	https://www.youtube.com/watch?v=rLGRSOfnnUM
6.9	Virtually Yours (Symbolics)	https://www.youtube.com/watch?v=BdTGJChDKrM
6.10	Digital Productions Demo – 1984	https://www.youtube.com/watch?v=N6u7yF2HtCw
6.11	Humantech	http://www.youtube.com/watch?v=c0mu8hnWSLg
6.12	Last Starfighter	http://www.youtube.com/watch?v=fEeGERPVxQU
6.13	Mick Jagger's Hard Woman	https://www.youtube.com/watch?v=LKcTGDBJUt8
6.14	Abel – Panasonic Glider	https://www.youtube.com/watch?v=3KFV0HbYULk
6.15	Abel Image Research High Fidelity – Excerpt (1982)	hi-fi.m4v
6.16	AT&T Ad	http://www.youtube.com/watch?v=IrnUdM_uF7s
6.17	Abel 1981 Demo	abel1981-excerpt.m4v
6.18	Abel 1982 Demo	http://www.youtube.com/watch?v=cT3_3d2JcR0
6.19	Abel 1985 Demo	http://www.youtube.com/watch?v=-1Yozk0g1YM
6.20	7-Up ad (1974)	https://www.youtube.com/watch?v=K2U-lP-SOSQ
6.21	Hawaiian Punch	http://www.youtube.com/watch?v=SIfh0XMrg6w
6.22	Benson and Hedges	http://www.youtube.com/watch?v=fdBoKOpctp4
6.23	Brilliance	http://www.youtube.com/watch?v=sCXYxNt02RI
6.24	Making of Brilliance	http://www.youtube.com/watch?v=eedXpclrKCc
6.25	C/CP NCGA Gears	CCP_NCGAGears-1.m4v
6.26	Cranston/Csuri Productions Demo – 1982	https://www.youtube.com/watch?v=ghNjMCHyu5w
6.27	Cranston/Csuri Productions Demo – 1983	http://www.youtube.com/watch?v=6EOFjHbiVMY
6.28	C/CP Demo – 1985	https://www.youtube.com/watch?v=Q8TYobTi234
6.29	C/CP TRW	http://www.youtube.com/watch?v=GvICw-8WaGk
6.30	C/CP Ads	http://www.youtube.com/watch?v=8CVkBZJ_zpI
6.31	PDI Morph Reel	https://www.youtube.com/watch?v=0b1_4NI3XIM
6.32	Pacific Data Images Demo – 1983	https://www.youtube.com/watch?v=b0cHnFxxLC4
6.33	Locomotion	https://www.youtube.com/watch?v=0b1_4NI3XIM
6.34	Chromosaurus	http://www.youtube.com/watch?v=HOUYSLStGak

Number	Title	URL
6.35	Waldo Demo w/ Jim Henson	https://www.youtube.com/watch?v=dP6TUB7KQc4
6.36	Richard Chuang Interview	http://www.youtube.com/watch?v=cQkEA62KWQQ
6.37	Omnibus Demo – 1985	https://www.youtube.com/watch?v=K18ZcE2t1Kw
6.38	Bo Gehring Demo – 1982	https://www.youtube.com/watch?v=Es8VdR-E8Wg
6.39	Harry Marks Demo	http://www.youtube.com/watch?v=6c3nWhR41D0
8.1	Alias/Wavefront Demo – 1986	https://www.youtube.com/watch?v=dolXi-3BcuA
8.2	Alias/Wavefront Demo – 1988	https://www.youtube.com/watch?v=2WU2Mckj15k
8.3	Wavefront Engineering Samples Reel	https://www.youtube.com/watch?v=0NY4dXRA3BM
8.4	Wavefront Users Group Demo	http://www.youtube.com/watch?v=3PBH0tvZCaE
8.5	Alias/Wavefront Maya Demo	https://www.youtube.com/watch?v=pHFLapfliN8
	Bill Buxton Movies	http://billbuxton.com/buxtonAliasVideos.html
8.6	Alias/Wavefront Maya Demo	https://www.youtube.com/watch?v=pHFLapfliN8
8.7	Side Effects 20th Anniversary Reel (2007)	https://www.youtube.com/watch?v=ScrDrCN5b5s
8.8	SoftImage Demo (1995)	https://www.youtube.com/watch?v=LrNQQvAKO2o
	Part 2	http://www.youtube.com/watch?v=xHeKXv4BY0M
8.9	Eurhythmy	eurythmy-1.m4v
8.10	Dancing Baby Cha	baby1-1.m4v
9.1	Larry Cuba – Calculated Movements	https://www.youtube.com/watch?v=HcvN1dt0yJo
	Interview with Larry Cuba	https://www.well.com/~cuba/VideoArt.html
	Star Wars: Episode IV – A New Hope. Making the graphics for Star Wars (Larry Cuba)	https://www.youtube.com/watch?v=yMeSw00n3Ac
	Lillian Schwartz – Artist and the Computer	http://www.lillian.com
	Lillian Schwartz – 3 Films and Interview	https://vimeo.com/31521570
9.2	Interview with Yoichiro Kawaguchi (1990) (Part 2)	https://www.youtube.com/watch?v=6qKjd0QXQO4
	Interview with Yoichiro Kawaguchi (1990) (Part 1)	http://www.youtube.com/watch?v=nJH0fLTR7YU
11.1	From Star Wars to Star Wars – The Story of ILM (1999)	https://www.youtube.com/watch?v=AFNTe7speqk
11.2	Jurassic Park excerpt – from ILM: Creating the Impossible	http://www.youtube.com/watch?v=NxfxsjCR_-o
11.3	André and Wally B.	https://www.youtube.com/watch?v=rQsCw1v-cEU
	The Making of Genesis	http://www.youtube.com/watch?v=Qe9qSLYK5q4
	Young Sherlock Holmes Knight	http://www.youtube.com/watch?v=uOsxXi-tu_U
	Pixar Image Computer	http://www.youtube.com/watch?v=ckE5U9FsgsE
11.4	Pixar Listerine Ad (1994)	https://www.youtube.com/watch?v=48tIwbuctYQ
11.5	Pixar – Luxo Jr.	https://www.youtube.com/watch?v=6G3O60o5U7w
	Pixar Shorts	http://www.youtube.com/watch?v=ckE5U9FsgsE

Number	Title	URL
	Pixar Executives Interview	http://www.youtube.com/watch?v=YjSExqtiIyg
11.6	Metrolight Demo	metrolight91-1.m4v
	Steam	https://www.youtube.com/watch?v=Qt87bLX7m_o
	Stanley and Stella – Breaking the Ice	http://www.youtube.com/watch?v=3bTqWsVqyzE
11.7	Technological Threat	https://www.youtube.com/watch?v=PLAGn3isH4o
11.8	Rhythm and Hues Demo – 1988	RHads-2.m4v
11.9	Making of Coca-Cola Bears	makeBears-1.m4v
11.10	Scenes from Lawnmower Man	lawnmower-1.m4v
11.11	Superman Movie Open	Superman-1.m4v
11.12	Bunny	https://www.youtube.com/watch?v=Gzv6WAlpENA
11.13	Maya	http://www.youtube.com/watch?v=a3KnzIdm7Aw
11.14	Sextone for President	http://www.youtube.com/watch?v=H9aYZ9KCWPk
11.15	Don't Touch Me – Dozo (1988)	https://www.youtube.com/watch?v=8ovn8qRezPA
11.16	500 Nations	https://www.youtube.com/watch?v=24IA_viq1ZY
11.17	Sogitec Demo – 1985	https://www.youtube.com/watch?v=S8gMdY9L7Wk
11.18	Stand By Me (Ex Machina)	http://www.youtube.com/watch?v=0MjoqsXkErA
11.19	Incredible Crash Dummies	https://www.youtube.com/watch?v=g-WgF5jGVdA
12.1	Scanimate	scanimate-1.m4v
12.2	A Conversation with Roy Weinstock	http://www.youtube.com/watch?v=n9CQddf-Bdw
12.3	Image West Demo – 1981	https://www.youtube.com/watch?v=ispW6-7b2sA
12.4	Ron Hays Music Image Demo	http://www.youtube.com/watch?v=kACpN3vhFtY
12.5	Quantel – PIP	olympic-pip-flame-1.m4v
12.6	Max Headroom	headroom-1.m4v
13.1	Flight Simulation	flightsim-1.m4v
13.2	Singer-Link Demo	https://www.youtube.com/watch?v=uy8sJ9AxvYI
13.3	Evans and Sutherland History	e-s-history-1.m4v
13.4	NASA Simulation (2004)	https://www.youtube.com/watch?v=QA1is2UtQnw
13.5	Beethoven's 6th in CIG	beethoven-2.m4v
13.6	Microsoft Flight Simulation	https://www.youtube.com/watch?v=ICb9ZXiD3q4
14.1	Animated Characters in Movies`	https://vimeo.com/14437767
14.2	Disney Silly Symphony: Farmyard Symphony (1938)	https://www.youtube.com/watch?v=5OVKAobiyIg
14.3	Queen: Bohemian Rhapsody	https://www.youtube.com/watch?v=irp8CNj9qBI
14.4	Cars: You Might Think	https://www.youtube.com/watch?v=3dOx510kyOs

Number	Title	URL
14.5	Rebecca Allen: Adventures in Success	https://www.youtube.com/watch?v=j5BLHeOdvYI
14.6	Rebecca Allen: Smile	https://www.youtube.com/watch?v=g43lzoRamWE
14.7	Money for Nothing Excerpt	https://www.youtube.com/watch?v=lAD6Obi7Cag
14.8	Peter Gabriel: Steam Excerpt	https://www.youtube.com/watch?v=Qt87bLX7m_o
14.9	Rebecca Allen – Musique	http://www.dailymotion.com/video/x175jh_kraftwerk-music-non-stop_
14.10	Michael Jackson: Black or White	https://www.youtube.com/watch?v=R4kLKv5gtxc
14.11	Godley & Creme: Cry Excerpt	https://www.youtube.com/watch?v=KxtPRF6NG7I
14.12	Todd Rundgren: Change Myself	https://vimeo.com/24768198
	Interview with Todd Rundgren	https://www.youtube.com/watch?v=Jhs24mL8Lx0
14.13	Def Leppard: Let's Get Rocked	https://www.youtube.com/watch?v=BO1Nae_EBvQ
14.14	Rammstein: Making of Links 2-3-4	https://www.youtube.com/watch?v=ax0G7MKe0hE
14.15	Creed: Bullets Excerpt	https://www.youtube.com/watch?v=oPzhUp8mWgs
14.16	Robbie Williams: Making of Rock D.J.	https://www.youtube.com/watch?v=Z4yO5yTW73I
14.17	TRON Trailer (1982)	https://www.youtube.com/watch?v=3efV2wqEjEY
15.1	SGI Iris 2400 Demo (1985)	https://www.youtube.com/watch?v=9EEY87HAHzk
15.2	NVIDIA Dawn (2002)	https://www.youtube.com/watch?v=4D2meIv08rQ
15.3	Spacewar! (1961)	https://www.youtube.com/watch?v=Rmvb4Hktv7U
15.4	Interview with Nolan Bushnell	https://www.youtube.com/watch?v=WW_rCV254yg
15.5	Interview with Ralph Baer	https://vimeo.com/37870722
16.1	Xerox Star Demo	https://www.youtube.com/watch?v=Cn4vC80Pv6Q
16.2	Macintosh 1984 Ad (with Jobs comments)	https://www.youtube.com/watch?v=lSiQA6KKyJo
	Macintosh 1984 Remake	http://www.youtube.com/watch?v=9pTHlG8USUg
16.3	Elton John: Nikita Excerpt	https://www.youtube.com/watch?v=Tg-Q-Acv4qs
16.4	Steve Jobs Introduces Macintosh (1984)	https://www.youtube.com/watch?v=2B-XwPjn9YY
16.5	Bill Gates and Steve Jobs (2007)	https://www.youtube.com/watch?v=1Bk-qTzN7vE
16.6	Gates/Jobs Rivalry	https://www.youtube.com/watch?v=P_5xhcpoeoM
16.7	Only Amiga!	https://www.youtube.com/watch?v=iNR5vxAR22A
16.8	Amiga and Newtek Toaster	https://www.youtube.com/watch?v=seznQmDp2pU
17.1	Aspen Map example	aspen-map-1.m4v
17.3	UNC Fetal Surgery Virtual Reality	fetal-surgery-1.m4v
18.1	Viz-O-Matic	https://www.youtube.com/watch?v=fP-7rhb-qMg
18.2	L.A.: The Movie (1987)	https://www.youtube.com/watch?v=6RsXCbpJG54

Number	Title	URL
18.3	Mars: The Movie (1989)	https://www.youtube.com/watch?v=vPXQq1XNi0c
18.4	NCSA Severe Storm Visualization	https://www.youtube.com/watch?v=EgumU0Ns1YI
18.5	Egyptology: 3D Mummy	https://www.youtube.com/watch?v=Il8gZbD9bkM
19.1	Particle Dreams – Sims	https://www.youtube.com/watch?v=tFD4jMMXRbg
19.2	Genesis Sequence – ILM	https://www.youtube.com/watch?v=Qe9qSLYK5q4
19.3	Panspermia – Sims	https://www.youtube.com/watch?v=F4asE2JdSOY
19.4	Locomotion	https://www.youtube.com/watch?v=Qe9qSLYK5q4
19.5	Evolved Creatures	http://www.youtube.com/watch?v=bBt0imn77Zg
19.6	Eurhythmy – Girard/Amkraut	https://www.youtube.com/watch?v=HLiD2yCBY8o
19.7	Stanley and Stella in Breaking the Ice	https://www.youtube.com/watch?v=3bTqWsVqyzE
19.8	Rigid Body Dynamics – 1987	https://www.youtube.com/watch?v=AmFYMbJ0Eew
19.9	Flow – Apple ATG	FLOW320-2.m4v
19.10	Her Majesty's Secret Service	https://www.youtube.com/watch?v=qtJmulx3c8E
19.11	Natural Phenomena	https://www.youtube.com/watch?v=gL7YiApRvFY
19.12	Vol Libre	https://vimeo.com/5810737
19.13	Fiat Lux	https://www.youtube.com/watch?v=IOuNA7mMgYY
19.14	Campanile	http://www.youtube.com/watch?v=RPhGEiM_6lM
19.15	Rendering with Natural Light	http://www.youtube.com/watch?v=fW_GPCR9_GU
19.16	Simulation of Parthenon Lighting	http://www.youtube.com/watch?v=bBt0imn77Zg
19.17	Interview with Paul Debevec	http://www.youtube.com/watch?v=VKx_DZp_0EI
19.18	I Have Never Seen, But I Know	https://www.youtube.com/watch?v=Xb50LQ8lhAU
19.19	More Bells and Whistles	http://www.youtube.com/watch?v=qSdR4gFumps
19.20	Stick Figures	https://www.youtube.com/watch?v=LM6kB6ce_5M
19.21	Pipe Dreams	https://www.youtube.com/watch?v=Xu-A0jqMPd8
19.22	Butterflies in the Rain	https://www.youtube.com/watch?v=lVXmtckavDQ
19.23	the end – Landreth	https://vimeo.com/23454509
19.24	Bingo – Landreth	https://vimeo.com/23191218

Photo Image Galleries

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4.2	Later CGRG Images	4.5 – The Ohio State University
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5.1	Cornell PCG Image Collection	5.1 – Cornell and NYIT
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5.3	Cal Tech Image Collection	5.3 – Cal Tech and NCSU
5.4	Circle Graphics Habitat Images	5.4 – Illinois-Chicago and Penn
5.5	Hiroshima University Images	5.5 Other Labs and NSF Tech Cen
6.1	Triple-I Image Collection	6.3 Information International Inc.
6.2	Digital Productions Image Collection	6.4 Digital Productions
6.3	Robert Abel & Associates Image Collection	6.5 Robert Abel & Associates
6.4	Cranston/Csuri Productions Image Collection	6.6 Cranston/Csuri Productions
9.1	David Em Artwork	9.6 David Em
9.2	Yoichiro Kawaguchi Artwork	9.7 Yoichiro Kawaguchi
11.1	Pixar Animation Studios Shorts	11.3 Pixar
11.2	Metrolight AMC Promo Images	11.4 Metrolight / Rezn8
12.1	SCANIMATE Image Collection	12.2 ANIMAC / SCANIMATE
12.2	Image West Image Collection	12.3 Image West / Dolphin Produc
12.3	Dolphin Studios Image Collection	12.3 Image West / Dolphin Produc
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13.1	Evans & Sutherland	13.3 Evans and Sutherland
13.2	Microsoft Flight Simulator Screenshots	13.6 Other Approaches
14.1	Peter Lloyd Designs (TRON)	14.3 Tron
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19.1	Industrial Light and Magic Particle System Images	19.1 Particle Systems and Artificia

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19.2	Karl Sims Research Images	19.1 Particle Systems and Artificia
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Glossary

A

A-buffer or Alpha-buffer

An extra Color channel to hold transparency information; pixels become quad values (RGBA). In a 32-bit frame buffer there are 24 bits of color, 8 each for red, green, and blue, along with an 8-bit alpha channel. Alpha is used for determining and displaying transparency, shadows, and anti-aliasing.

Related Glossary Terms: Antialiasing, Frame buffer

Term Source: Chapter 19 – Noise functions and Fractals

Abel, Robert

Robert Abel was a pioneer in visual effects, computer animation and interactive media, best known for the work of his company, Robert Abel and Associates. He received degrees in Design and Film from UCLA. He began his work in computer graphics in the 1950s, as an apprentice to John Whitney. In the 1960s and early 1970s, Abel wrote or directed several films, including The Making of the President, 1968, Elvis on Tour and Let the Good Times Roll.

In 1971, Abel and Con Pederson founded Robert Abel and Associates (RA&A), creating slit- scan effects and using motion-controlled cameras for television commercials and films. RA&A began using Evans & Sutherland computers to pre-visualize their effects; this led to the creation of the trailer for The Black Hole, and the development of their own software for digitally animating films (including Tron).In 1984, Robert Abel and Associates produced a commercial named Brilliance for the Canned Food Information Council for airing during the Super Bowl. It featured a sexy robot with reflective environment mapping and human-like motion.

Abel & Associates closed in 1987 following an ill-fated merger with now defunct Omnibus Computer Graphics, Inc., a company which had been based in Toronto.In the 1990s, Abel founded Synapse Technologies, an early interactive media company, which produced pioneering educational projects for IBM, including “Columbus: Discovery, Encounter and Beyond” and “Evolution/Revolution: The World from 1890-1930”.He received numerous honors, including a Golden Globe Award (for Elvis on Tour), 2 Emmy Awards, and 33 Clios.

Abel died from complications following a myocardial infarction at the age of 64.

Related Glossary Terms: DOA

Term Source: Chapter 6 – Robert Abel and Associates

Abstract expressionism

A painting movement in which artists typically applied paint rapidly, and with force to their huge canvases in an effort to show feelings and emotions, painting gesturally, non- geometrically, sometimes applying paint with large brushes, sometimes dripping or even throwing it onto canvas. Their work is characterized by a strong dependence on what appears to be accident and chance, but which is actually highly planned. Some Abstract Expressionist artists were concerned with adopting a peaceful and mystical approach to a purely abstract image. Usually there was no effort to represent subject matter. Not all work was abstract, nor was all work expressive, but it was generally believed that the spontaneity of the artists' approach to their work would draw from and release the creativity of their unconscious minds. The expressive method of painting was often considered as important as the painting itself.

Related Glossary Terms:

Term Source: Chapter 9 – Ed Emshwiller

Affine transformation

In geometry, an affine transformation or affine map or an affinity (from the Latin, affinis, "connected with") is a transformation which preserves straight lines (i.e., all points lying on a line initially still lie on a line after transformation) and ratios of distances between points lying on a straight line (e.g., the midpoint of a line segment remains the midpoint after transformation). It does not necessarily preserve angles or lengths.

Related Glossary Terms:

Term Source: Chapter 19 – Plants

Alpha channel

the concept of an alpha channel was introduced by Alvy Ray Smith in the late 1970s, and fully developed in a 1984 paper by Thomas Porter and Tom Duff. In a 2D image element, which stores a color for each pixel, additional data is stored in the alpha channel with a value between 0 and 1. A value of 0 means that the pixel does not have any coverage information and is transparent; i.e. there was no color contribution from any geometry because the geometry did not overlap this pixel. A value of 1 means that the pixel is opaque because the geometry completely overlapped the pixel.

Related Glossary Terms: Frame buffer

Term Source: Chapter 5 – Cornell and NYIT, Chapter 15 – Early hardware

Analog

Relating to, or being a device in which data are represented by continuously variable, measurable, physical quantities, such as length, width, voltage, or pressure; a device having an output that is proportional to the input.

Related Glossary Terms: Digital

Term Source: Chapter 1 – Early analog computational devices

Anisotropic reflection

Anisotropic Reflections are just like regular reflections, except stretched or blurred based on the orientation of small grooves (bumps, fibers or scratches) that exist on a reflective surface. The kinds of objects include anything that has a fine grain that goes all in predominantly one direction. Good everyday examples would be hair, brushed metals, pots and pans, or reflections in water that's being perturbed (for example, by falling rain).

Related Glossary Terms:

Term Source: Chapter 5 – Cal Tech and North Carolina State

Antialiasing

antialiasing is a software technique for diminishing jaggies – stair-step-like lines that should be smooth. Jaggies occur because the output device, the monitor or printer, doesn't have a high enough resolution to represent a smooth line. Antialiasing reduces the prominence of jaggies by surrounding the stair-steps with intermediate shades of gray (for gray-scaling devices) or color (for color devices). Although this reduces the jagged appearance of the lines, it also makes them fuzzier.

Related Glossary Terms: A-buffer or Alpha-buffer, Jaggies

Term Source: Chapter 15 – Early hardware

API

API, an abbreviation of application program interface, is a set of routines, protocols, and tools for building software applications. A good API makes it easier to develop a program by providing all the building blocks. A programmer then puts the blocks together.

Most operating environments, such as the Apple Quartz API, provide an API so that programmers can write

applications consistent with the operating environment. Although APIs are designed for programmers, they are ultimately good for users because they guarantee that all programs using a common API will have similar interfaces. This makes it easier for users to learn new programs.

Related Glossary Terms:

Term Source: Chapter 15 – Graphics Accelerators

Atkinson, Bill

Bill Atkinson is a computer engineer and photographer. Atkinson worked at Apple Computer from 1978 to 1990. He received his undergraduate degree from the University of California, San Diego, where Apple Macintosh developer Jef Raskin was one of his professors. Atkinson continued his studies as a graduate student at the University of Washington. Atkinson was part of the Apple Macintosh development team and was the creator of the ground-breaking MacPaint application, among others. He also designed and implemented QuickDraw, the fundamental toolbox that the Macintosh used for graphics. QuickDraw's performance was essential for the success of the Macintosh's graphical user interface. Atkinson also designed and implemented HyperCard, the first popular hypermedia system.

Related Glossary Terms:

Term Source: Chapter 16 – Apple Computer

Augmented reality

Augmented reality (AR) is a live, direct or indirect, view of a physical, real-world environment whose elements are augmented by computer-generated sensory input such as sound, video, graphics or GPS data. It is related to a more general concept called mediated reality, in which a view of reality is modified (possibly even diminished rather than augmented) by a computer. As a result, the technology functions by enhancing one's current perception of reality. By contrast, virtual reality replaces the real world with a simulated one.

Related Glossary Terms: Virtual reality

Term Source: Chapter 17 – Virtual Reality

B

B-rep

In solid modeling and computer-aided design, boundary representation—often abbreviated as B-rep or BREP—is

a method for representing shapes using the limits. A solid is represented as a collection of connected surface elements, the boundary between solid and non-solid.

Boundary representation models are composed of two parts: topology and geometry (surfaces, curves and points). The main topological items are: faces, edges and vertices. A face is a bounded portion of a surface; an edge is a bounded piece of a curve and a vertex lies at a point. Other elements are the shell (a set of connected faces), the loop (a circuit of edges bounding a face) and loop-edge links (also known as winged edge links or half- edges) which are used to create the edge circuits. The edges are like the edges of a table, bounding a surface portion.

Related Glossary Terms: Solids modeling

Term Source: Chapter 10 – SDRC / Unigraphics

Badler, Norman

Norman I. Badler is professor of computer and information science at the University of Pennsylvania and has been on that faculty since 1974. He has been active in computer graphics since 1968, with research interests centered on computational connections between language and human action. Badler received the B.A. degree in creative studies mathematics from the University of California at Santa Barbara in 1970. He received the M.Sc. in mathematics in 1971 and the Ph.D. in computer science in 1975, both from the University of Toronto. He directs the SIG Center for Computer Graphics and the Center for Human Modeling and Simulation at Penn.

Related Glossary Terms:

Term Source: Chapter 5 – Illinois-Chicago and University of Pennsylvania

Baecker, Ron

Dr. Baecker is an expert in human-computer interaction (“HCI”) and user interface (“UI”) design. His research interests include work on electronic memory aids and other cognitive prostheses; computer applications in education; computer-supported cooperative learning, multimedia and new media; software visualization; groupware and computer-supported cooperative work; computer animation and interactive computer graphics; computer literacy and how computers can help us work better and safer; and entrepreneurship and the management of small business as well as the stimulation of innovation. Baecker is also interested in the social implications of computing, especially the issue of responsibility when humans and computers interact.

Related Glossary Terms:

Term Source: Chapter 5 – UNC and Toronto

Baraff, David

David Baraff is a Senior Animation Scientist at Pixar Animation Studios. He received a BsE in Computer Science from the University of Pennsylvania, and a Ph.D. in Computer Science from Cornell. From 1992 to 1998 Baraff was a Professor of Robotics at Carnegie Mellon University in Pennsylvania. Simulation software from Physical Effects, Inc., a software company he co-founded, has been used in numerous movies at studios outside of Pixar. In 2006 he received a Scientific and Technical Academy Award for his work on cloth simulation.

Related Glossary Terms:

Term Source: Chapter 19 – Physical-based Modeling

Barr, Al

Al Barr, PhD RPI, now on the faculty at Caltech, works “to enhance the mathematical and scientific foundations of computer graphics, extending it beyond mere picture-making to the point that reconfigurable models have great predictive power.

Related Glossary Terms:

Term Source: Chapter 5 – Cal Tech and North Carolina State

Bass, Saul

Saul Bass was a graphic designer and filmmaker, perhaps best known for his design of film posters and motion picture title sequences. During his 40-year career Bass worked for some of Hollywood’s greatest filmmakers, including Alfred Hitchcock, Otto Preminger, Billy Wilder, Stanley Kubrick and Martin Scorsese. Amongst his most famous title sequences are the animated paper cut-out of a heroin addict’s arm for Preminger’s The Man with the Golden Arm, the credits racing up and down what eventually becomes a high-angle shot of the C.I.T. Financial Building in Hitchcock’s North by Northwest, and the disjointed text that races together and apart in Psycho.

Bass designed some of the most iconic corporate logos in North America, including the AT&T “bell” logo in 1969, as well as AT&T’s “globe” logo in 1983 after the breakup of the Bell System. He also designed Continental Airlines’ 1968 “jetstream” logo and United Airlines’ 1974 “tulip” logo which became some of the most recognized airline industry logos of the era.

Related Glossary Terms:

Term Source: Chapter 6 – Robert Abel and Associates

Bergeron, Philippe

Philippe Bergeron holds a B.Sc. and M.Sc. in Computer Science from University of Montreal. He wrote over a dozen articles on computer graphics. He co-directed the short “Tony de Peltrie,” the world’s first 3-D CGI human

with emotions. It closed SIGGRAPH'85. He was technical research director at Digital Productions, and head of Production Research at Whitney/Demos Productions where he character animated "Stanley and Stella in Breaking The Ice." Bergeron is also an actor and landscape designer.

Related Glossary Terms:

Term Source: Chapter 8 – Introduction

Bezier curves

A Bézier curve is a parametric curve frequently used in computer graphics and related fields. Generalizations of Bézier curves to higher dimensions are called Bézier surfaces, of which the Bézier triangle is a special case.

In vector graphics, Bézier curves are used to model smooth curves that can be scaled indefinitely. "Paths," as they are commonly referred to in image manipulation programs, are combinations of linked Bézier curves. Paths are not bound by the limits of rasterized images and are intuitive to modify. Bézier curves are also used in animation as a tool to control motion

Related Glossary Terms:

Term Source: Chapter 14 – CGI and Effects in Films and Music Videos

Bézier, Pierre

Pierre Étienne Bézier was a French engineer and one of the founders of the fields of solid, geometric and physical modeling as well as in the field of representing curves, especially in CAD/CAM systems. As an engineer at Renault, he became a leader in the transformation of design and manufacturing, through mathematics and computing tools, into computer-aided design and three-dimensional modeling. Bézier patented and popularized, but did not invent the Bézier curves and Bézier surfaces that are now used in most computer-aided design and computer graphics systems.

Related Glossary Terms:

Term Source: Chapter 4 – Other research efforts

Bit BLT

Bit BLT (which stands for bit-block [image] transfer but is pronounced bit blit) is a computer graphics operation in which several bitmaps are combined into one using a raster operator.

The operation involves at least two bitmaps, a source and destination, possibly a third that is often called the

“mask” and sometimes a fourth used to create a stencil. The pixels of each are combined bitwise according to the specified raster operation (ROP) and the result is then written to the destination.

This operation was created by Dan Ingalls, Larry Tesler, Bob Sproull, and Diana Merry at Xerox PARC in November 1975 for the Smalltalk-72 system.

Related Glossary Terms:

Term Source: Chapter 15 – Early hardware, Chapter 16 – Xerox PARC

Blinn, James

James F. Blinn is a computer scientist who first became widely known for his work as a computer graphics expert at NASA’s Jet Propulsion Laboratory (JPL), particularly his work on the pre-encounter animations for the Voyager project, his work on the Carl Sagan Cosmos documentary series and the research of the Blinn–Phong shading model.

Blinn devised new methods to represent how objects and light interact in a three dimensional virtual world, like environment mapping and bump mapping. He is well known for creating animation for three television series: Carl Sagan’s Cosmos: A Personal Voyage; Project MATHEMATICS!; and the pioneering instructional graphics in The Mechanical Universe. His simulations of the Voyager spacecraft visiting Jupiter and Saturn have been seen widely. He is now a graphics fellow at Microsoft Research. Blinn also worked at the New York Institute of Technology in the summer of 1976

Related Glossary Terms:

Term Source: Chapter 4 – JPL and National Research Council of Canada

Blue Screen

Chroma key compositing, or chroma keying, is a special effects / post-production technique for compositing (layering) two images or video streams together, used heavily in many fields to remove a background from the subject of a photo or video – particularly the newscasting, motion picture and videogame industries. A color range in the top layer is made transparent, revealing another image behind. The chroma keying technique is commonly used in video production and post-production. This technique is also referred to as color keying, color-separation overlay (CSO), or by various terms for specific color- related variants such as green screen, and blue screen – chroma keying can be done with backgrounds of any color that are uniform and distinct, but green and blue backgrounds are more commonly used because they differ most distinctly in hue from most human skin colors and no part of the subject being filmed or photographed may duplicate a color used in the background

Related Glossary Terms: Chroma key compositing

Term Source: Chapter 14 – CGI and Effects in Films and Music Videos

Brooks, Frederick

Frederick Phillips Brooks, Jr. is a software engineer and computer scientist, best known for managing the development of IBM's System/360 family of computers and the OS/360 software support package, then later writing candidly about the process in his seminal book The Mythical Man-Month. Brooks has received many awards, including the National Medal of Technology in 1985 and the Turing Award in 1999. It was in The Mythical Man- Month that Brooks made the now-famous statement: "Adding manpower to a late software project makes it later." This has since come to be known as the Brooks's law.

Related Glossary Terms:

Term Source: Chapter 17 – Interaction

Bump mapping

Bump mapping is a technique in computer graphics for simulating bumps and wrinkles on the surface of an object. This is achieved by perturbing the surface normals of the object and using the perturbed normal during lighting calculations. The result is an apparently bumpy surface rather than a smooth surface although the surface of the underlying object is not actually changed. Bump mapping was introduced by Blinn in 1978

Related Glossary Terms: Blinn, University of Utah

Term Source:

Burtnyk, Nestor

NRC scientists Nestor Burtnyk and Marceli Wein, were recently honored at the Festival of Computer Animation in Toronto. They were recognized as Fathers of Computer Animation Technology in Canada. Burtnyk, who began his career with NRC in 1950, started Canada's first substantive computer graphics research project in the 1960s. Wein, who joined this same project in 1966, had been exposed to the potential of computer imaging while studying at McGill. He teamed up with Burtnyk to pursue this promising field.

One of their main contributions was the Academy Award nominated film "Hunger/La Faim" (produced by the National Film Board of Canada) using their famous key-frame animation approach and system.

Related Glossary Terms: Wein, Marceli

Term Source: Chapter 4 – JPL and National Research Council of Canada

Buxton, Bill

William Arthur Stewart “Bill” Buxton (born March 10, 1949) is a Canadian computer scientist and designer. He is currently a Principal researcher at Microsoft Research. He is known for being one of the pioneers in the human–computer interaction field.

Related Glossary Terms:

Term Source: Chapter 5 – UNC and Toronto

C

CAD

CAD – computer-aided design

The use of computer programs and systems to design detailed two- or three-dimensional models of physical objects, such as mechanical parts, buildings, and molecules.

Related Glossary Terms: CADD, CAE, CAID, CAM

Term Source: Chapter 3 – General Motors DAC, Chapter 10 – Introduction, Chapter 10 – Introduction

CADD

CADD – Computer Aided Drafting and Design, Computer-Aided Design & Drafting, or Computer-Aided Design Development

The use of the computer to help with the drafting of product plans.

Related Glossary Terms:CAD, CAE, CAID, CAM

Term Source: Chapter 3 – General Motors DAC Chapter 10 – Introduction

CAE

CAE – computer-aided engineering

Use of computers to help with all phases of engineering design work. Like computer aided design, but also involving the conceptual and analytical design steps.

Related Glossary Terms: CADD, CAD, CAID, CAM

Term Source: Chapter 10 – Introduction Chapter 10 – SDRC / Unigraphics

CAID

Computer-aided industrial design (CAID) is CAD adapted and specialized for aesthetic design. From a designer's point of view, CAD is for the pocket-protector brigade, while CAID is for the creative.

Related Glossary Terms: CADD, CAE, CAD, CAM

Term Source: Chapter 8 – Alias Research

CAM

CAM – computer-aided manufacturing

The process of using specialized computers to control, monitor, and adjust tools and machinery in manufacturing.

Related Glossary Terms: CADD, CAE, CAID, CAD

Drag related terms here

Term Source: Chapter 10 – Introduction, Chapter 10 – MCS / CalComp / McAuto

Carpenter, Loren

Loren Carpenter is a computer graphics researcher and developer. He is co-founder and chief scientist of Pixar Animation Studios and the co-inventor of the Reyes rendering algorithm. He is one of the authors of the PhotoRealistic RenderMan software which implements Reyes and is used to create the imagery for Pixar's movies. Following Disney's acquisition of Pixar, Carpenter became a Senior Research Scientist at Disney Research.[1]

Carpenter began work at Boeing Computer Services in Seattle, Washington. In 1980 he gave a presentation at the SIGGRAPH conference, in which he showed "Vol Libre", a 2 minute computer generated movie. This showcased his software for generating and rendering fractally generated landscapes. At Pixar Carpenter worked on the "genesis effect" scene of Star Trek II: The Wrath of Khan, which featured an entire fractally- landscaped planet.

Related Glossary Terms:

Term Source: Chapter 19 – Noise functions and Fractals

Cathode Ray Tube

A vacuum tube generating a focused beam of electrons that can be deflected by electric fields, magnetic fields, or both. The terminus of the beam is visible as a spot or line of luminescence caused by its impinging on a sensitized screen at one end of the tube. Cathode-ray tubes are used to study the shapes of electric waves, to reproduce images in television receivers, to display alphanumeric and graphical information on computer monitors, as an indicator in radar sets, etc. Abbreviation: CRT

Related Glossary Terms: Vacuum tube

Term Source: Chapter 1 – Electronic devices

Caustics

In optics, a caustic or caustic network is the envelope of light rays reflected or refracted by a curved surface or object, or the projection of that envelope of rays on another surface. The caustic is a curve or surface to which each of the light rays is tangent, defining a boundary of an envelope of rays as a curve of concentrated light. Therefore in an image the caustics can be the patches of light or their bright edges. These shapes often have cusp singularities.

In computer graphics, most modern rendering systems support caustics. Some of them even support volumetric caustics. This is accomplished by raytracing the possible paths of the light beam through the glass, accounting for the refraction and reflection. Photon mapping is one implementation of this.

Related Glossary Terms: Photon mapping, Ray-trace

Term Source: Chapter 20 – CG Icons

Charactron

a cathode-ray tube used in information display units to reproduce letters, numbers, map symbols, and other characters. Invented in the USA in 1941, the Charactron is an instantaneous-operation numerical indicator tube.

In the Charactron, the characters reproduced on the tube’s screen are formed by means of a matrix, which is an opaque plate containing a set of 64 to 200 microscopic openings in the shape of the characters to be displayed. The matrix is located in the path of the electron beam between two deflection systems. The first deflection system guides the beam to the desired character on the matrix; the second system guides the shaped beam to the desired location on the screen. When the beam passes through the matrix, the cross section of the beam takes on the shape of the character through which it has passed. Hence, an image of the desired character—rather than a point, as in ordinary cathode-ray tubes—is illuminated at the place where the beam strikes the screen.

Related Glossary Terms:

Term Source: Chapter 3 – Other output devices

Chroma key compositing

Chroma key compositing, or chroma keying, is a special effects / post-production technique for compositing (layering) two images or video streams together, used heavily in many fields to remove a background from the subject of a photo or video – particularly the newscasting, motion picture and video game industries. A color range in the top layer is made transparent, revealing another image behind. The chroma keying technique is commonly used in video production and post-production. This technique is also referred to as color keying, color-separation overlay (CSO), or by various terms for specific color- related variants such as green screen, and blue screen – chroma keying can be done with backgrounds of any color that are uniform and distinct, but green and blue backgrounds are more commonly used because they differ most distinctly in hue from most human skin colors and no part of the subject being filmed or photographed may duplicate a color used in the background

Related Glossary Terms: Blue Screen

Term Source:

Clipping

Any procedure which identifies that portion of a picture which is either inside or outside a region to be displayed on a CRT or screen is referred to as a clipping algorithm or clipping.

The region against which an object is to be clipped is called clipping window.

Related Glossary Terms:

Term Source: Chapter 3 – General Motors DAC, Chapter 4 – MIT and Harvard

Colormap

Color mapping is a function that maps (transforms) the colors of one (source) image to the colors of another (target) image. A color mapping may be referred to as the algorithm that results in the mapping function or the algorithm that transforms the image colors. Color mapping is also sometimes called color transfer or, when grayscale images are involved, brightness transfer function (BTF).

Related Glossary Terms:

Term Source: Chapter 18 – Hardware and Software

Combinatorial geometry

Computational (sometimes referred to as combinatorial) geometry is a branch of computer science devoted to the study of algorithms which can be stated in terms of geometry. Some purely geometrical problems arise out of the

study of computational geometric algorithms, and such problems are also considered to be part of computational geometry.

The main impetus for the development of computational geometry as a discipline was progress in computer graphics and computer-aided design and manufacturing (CAD/CAM), but many problems in computational geometry are classical in nature, and may come from mathematical visualization.

Related Glossary Terms:

Term Source: Chapter 6 – MAGI

Computational fluid dynamics

Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions.

Related Glossary Terms:

Term Source: Chapter 18 – Introduction

Computer graphics

1. pictorial computer output produced on a display screen, plotter, or printer.
2. the study of the techniques used to produce such output.
3. the use of a computer to produce and manipulate pictorial images on a video screen, as in animation techniques or the production of audiovisual aids

Related Glossary Terms:

Term Source: Preface – Preface

Computer-generated art

Digital art is a general term for a range of artistic works and practices that use digital technology as an essential part of the creative and/or presentation process. Since the 1970s, various names have been used to describe the process including computer art, computer-generated art, and multimedia art, and digital art is itself placed under the larger umbrella term new media art.

Related Glossary Terms:

Term Source: Chapter 9 – Lillian Schwartz

Constructivist

Constructivism, Russian *Konstruktivizm*, Russian artistic and architectural movement that was first influenced by Cubism and Futurism and is generally considered to have been initiated in 1913 with the "painting reliefs"—abstract geometric constructions—of Vladimir Tatlin.

Related Glossary Terms:

Term Source: Chapter 9 – Manfred Mohr

Continuous shading

Continuous shading is the smooth shading of polygons with bilinear interpolation. In other words, the brightness of the shading varies within individual polygons, without altering the color being applied. It is often referred to as Gouraud shading.

Related Glossary Terms: Gouraud shading

Term Source: Chapter 17 – Virtual Reality

Contour plots

A contour plot is a graphical technique for representing a 3-dimensional surface by plotting constant z slices, called contours, on a 2-dimensional format. That is, given a value for z, lines are drawn for connecting the (x,y) coordinates where that z value occurs.

The contour plot is an alternative to a 3-D surface plot.

Related Glossary Terms: Isolines, Isosurfaces

Term Source: Chapter 18 – Algorithms

Coons, Steven

Steven Anson Coons (March 7, 1912 – August 1979) was an early pioneer in the field of computer graphical methods. He was a professor at the Massachusetts Institute of Technology in the Mechanical Engineering Department. Steven Coons had a vision of interactive computer graphics as a design tool to aid the engineer.

The Association for Computing Machinery SIGGRAPH has an award named for Coons. The Steven Anson Coons Award for Outstanding Creative Contributions to Computer Graphics is given in odd-numbered years to

an individual to honor that person's lifetime contribution to computer graphics and interactive techniques. It is considered the field's most prestigious award.

Related Glossary Terms:

Term Source: Chapter 4 – MIT and Harvard

Core memory

Magnetic-core memory was the predominant form of random-access computer memory for 20 years (circa 1955–75). It uses tiny magnetic toroids (rings), the cores, through which wires are threaded to write and read information. Each core represents one bit of information. The cores can be magnetized in two different ways (clockwise or counterclockwise) and the bit stored in a core is zero or one depending on that core's magnetization direction. The wires are arranged to allow an individual core to be set to either a "one" or a "zero", and for its magnetization to be changed, by sending appropriate electric current pulses through selected wires. The process of reading the core causes the core to be reset to a "zero", thus erasing it. This is called destructive readout.

Such memory is often just called core memory, or, informally, core. Although core memory had been superseded by semiconductor memory by the end of the 1970s, memory is still occasionally called "core"

Each core was a donut shaped metal, often ferrite, that had two electrical wires strung through it. Neither wire was strong enough in power to change the state of the magnetism of the core, but together they were. Thus it was a randomly addressable storage and access medium.

Related Glossary Terms:

Term Source: Chapter 2 – Whirlwind and SAGE

Cray

Cray Inc.is an American supercomputer manufacturer based in Seattle, Washington. The company's predecessor, Cray Research, Inc. (CRI), was founded in 1972 by computer designer Seymour Cray. Seymour Cray went on to form the spin-off Cray Computer Corporation (CCC), in 1989, which went bankrupt in 1995, while Cray Research was bought by SGI the next year. Cray Inc. was formed in 2000 when Tera Computer Company purchased the Cray Research Inc. business from SGI and adopted the name of its acquisition. Their computers included the Cray-1, Cray-2, and Cray X-MP

Related Glossary Terms:

Term Source: Chapter 6 – Digital Productions (DP)

CSG

Constructive solid geometry (CSG) is a technique used in solid modeling. Constructive solid geometry allows a modeler to create a complex surface or object by using Boolean operators to combine objects. Often CSG presents a model or surface that appears visually complex, but is actually little more than cleverly combined or decombined objects.

In 3D computer graphics and CAD CSG is often used in procedural modeling. CSG can also be performed on polygonal meshes, and may or may not be procedural and/or parametric.

Related Glossary Terms: Solids modeling

Term Source: Chapter 10 – Introduction

Csuri, Charles

Charles Csuri is best known for pioneering the field of computer graphics, computer animation and digital fine art, creating the first computer art in 1964. Csuri has been recognized as the father of digital art and computer animation by Smithsonian, and as a leading pioneer of computer animation by the Museum of Modern Art (MoMA) and The Association for Computing Machinery Special Interest Group Graphics (ACM SIGGRAPH). Between 1971 and 1987, while a senior professor at the Ohio State University, Charles Csuri founded the Computer Graphics Research Group, the Ohio Super Computer Graphics Project, and the Advanced Computing Center for Art and Design, dedicated to the development of digital art and computer animation. Csuri was co-founder of Cranston/ Csuri Productions (C/CP), one of the world's first computer animation production companies.

Related Glossary Terms: The Ohio State University

Term Source: Chapter 4 – University of Utah, Chapter 4 – The Ohio State University

Cuba, Larry

Larry Cuba is a computer-animation artist who became active in the late 1970s and early 80s. He received A.B. from Washington University in St. Louis in 1972 and his Master's Degree from California Institute of the Arts In 1975, John Whitney, Sr. invited Cuba to be the programmer on one of his films. The result of this collaboration was "Arabesque". Subsequently, Cuba produced three more computer-animated films: 3/78 (Objects and Transformations), Two Space, and Calculated Movements. Cuba also produced computer graphics for Star Wars Episode IV: A New Hope in 1977 on Tom DeFanti's Grass system at EVL. His animation of the Death Star is shown to pilots in the Rebel Alliance. Cuba received grants for his work from the American Film Institute and The National Endowment for the Arts

Related Glossary Terms: EVL

Term Source: Chapter 9 – Larry Cuba

D

DAC-1

DAC-1, for Design Augmented by Computer, was one of the earliest graphical computer aided design systems. Developed by General Motors, IBM was brought in as a partner in 1960 and the two developed the system and released it to production in 1963. It was publicly unveiled at the fall Joint Computer Conference in Detroit 1964. GM used the DAC system, continually modified, into the 1970s when it was succeeded by CADANCE.

Related Glossary Terms:

Term Source: Chapter 3 – General Motors DAC

Data-driven

Computer graphics visualization has evolved by focusing algorithmic approaches to the synthesis of imagery. Recently, various methods have been introduced to exploit pre- recorded data to improve the performance and/or realism of things like dynamic deformations. This data can guide the algorithms, or in some cases determine which algorithms are used in the synthesis process. It has seen successful usage in visualizations of music, dynamic deformation of faces, soft volumetric tissue, and cloth, as examples.

Related Glossary Terms:

Term Source: Chapter 19 – Data-driven Imagery

Dataflow

Dataflow is a software architecture based on the idea that changing the value of a variable should automatically force recalculation of the values of variables which depend on its value.

There have been a few programming languages created specifically to support dataflow. In particular, many (if not most) visual programming languages have been based on the idea of dataflow.

Related Glossary Terms: Modular visualization environments

Term Source: Chapter 18 – Visualization Systems

Debevec, Paul

Paul Debevec is a researcher in computer graphics at the University of Southern California's Institute for Creative Technologies. He is best known for his pioneering work in high dynamic range imaging and image-based modeling and rendering. Debevec received a Ph.D. in computer science from UC Berkeley in 1996; his

thesis research was in photogrammetry, or the recovery of the 3D shape of an object from a collection of still photographs taken from various angles.In 1997 he and a team of students produced The Campanile Movie, a virtual flyby of UC Berkeley's famous Campanile tower. Debevec's more recent research has included methods for recording real-world illumination for use in computer graphics; a number of novel inventions for recording ambient and incident light have resulted from the work of Debevec and his team, including the light stage, of which five or more versions have been constructed, each an evolutionary improvement over the previous. Techniques based on Debevec's work have been used in several major motion pictures, including The Matrix (1999), Spider-Man 2 (2004), King Kong (2005), Superman Returns (2006), Spider-Man 3 (2007), and Avatar (2009). In addition Debevec and his team have produced several short films that have premiered at SIGGRAPH's annual Electronic Theater, including Fiat Lux (1999) and The Parthenon (2004).

Debevec, along with Tim Hawkins, John Monos and Mark Sagar, was awarded a 2009 Scientific and Engineering Award from the Academy of Motion Picture Arts and Sciences for the design and engineering of the Light Stage capture devices and the image-based facial rendering system developed for character relighting in motion pictures.

Related Glossary Terms:

Term Source: Chapter 19 – Global Illumination

DeFanti, Tom

Tom DeFanti is a computer graphics researcher and pioneer. His work has ranged from early computer animation, to scientific visualization, virtual reality, and grid computing. He is a distinguished professor of Computer Science at the University of Illinois at Chicago, and a research scientist at the California Institute for Telecommunications and Information Technology. DeFanti did his PhD work in the early 1970s at Ohio State University, under Charles Csuri in the Computer Graphics Research Group. For his dissertation, he created the GRASS programming language, a three-dimensional, real-time animation system usable by computer novices.

In 1973, he joined the faculty of the University of Illinois at Chicago. With Dan Sandin, he founded the Circle Graphics Habitat, now known as the Electronic Visualization Laboratory (EVL). At UIC, DeFanti further developed the GRASS language, and later created an improved version, ZGRASS. The GRASS and ZGRASS languages have been used by a number of computer artists, including Larry Cuba, in his film 3/78 and the animated Death Star sequence for Star Wars. Later significant work done at EVL includes development of the graphics system for the Bally home computer, invention of the first data glove, co- editing the 1987 NSF-sponsored report Visualization in Scientific Computing that outlined the emerging discipline of scientific visualization, invention of PHSColograms, and invention of the CAVE Automatic Virtual Environment.

DeFanti contributed greatly to the growth of the SIGGRAPH organization and conference. He served as Chair of the group from 1981 to 1985, co-organized early film and video presentations (which became the Electronic Theatre), and in 1979 started the SIGGRAPH Video Review, a video archive of computer graphics research.

DeFanti is a Fellow of the Association for Computing Machinery. He has received the 1988 ACM Outstanding Contribution Award, the 2000 SIGGRAPH Outstanding Service Award, and the UIC Inventor of the Year Award.

Related Glossary Terms:EVL, Sandin, Dan

Term Source: Chapter 5 – Illinois-Chicago and University of Pennsylvania

DeGraf, Brad

DeGraf has been an innovator in computer animation in the entertainment industry since 1982, particularly in the areas of realtime characters, ride films, and the Web. He founded and/or managed several ground-breaking animation studios including Protozoa (aka Dotcomix), Colossal Pictures Digital Media, deGraf/Wahrman, and Digital Productions. In 2000, Wired called Brad “an icon in the world of 3D animation”. Brad is currently CEO and co-founder (with Michael Tolson formerly of XAOS and Envoii) of Sociative Inc.

His film credits include: Duke2000.com, a campaign with Garry Trudeau to get his Ambassador Duke character elected president; Moxy, emcee for the Cartoon Network, the first virtual character for television; Floops, the first Web episodic cartoon; Peter Gabriel’s Grammy award- winning video, Steam; “The Funtastic World of Hanna-Barbera”, the first computer-generated ride film; Feature films “The Last Starfighter”, “2010″, “Jetsons: the Movie”, “Robocop 2″,

Related Glossary Terms:

Term Source: Chapter 6 – Digital Productions (DP)

Demos, Gary

Gary Demos was one of the principals of the Motion Picture Project at Information International Inc. (1974–1981), Digital Productions (1981–1986), and Whitney/Demos Productions (1986–1988). In 1988 Demos formed DemoGraFX, which became involved in technology research for advanced television systems and digital cinema, as well as consulting and contracting for computer companies and visual effects companies. DemoGraFX was sold to Dolby Labs in 2003. Demos attended Cal Tech and worked with Ivan Sutherland at E&S and later at the Picture/Design Group before co-founding the graphics group at Triple-I.

Related Glossary Terms: DOA

Term Source: Chapter 6 – Digital Productions (DP)

Diffuse reflection

Diffuse reflection is the reflection of light from a surface such that an incident ray is reflected at many angles rather than at just one angle as in the case of specular reflection. An illuminated ideal diffuse reflecting surface will have equal luminance from all directions in the hemisphere surrounding the surface (Lambertian reflectance).

Related Glossary Terms: Lambertian, Specular reflection

Term Source:

Digital

A description of data which is stored or transmitted as a sequence of discrete symbols from a finite set, most commonly this means binary data represented using electronic or electromagnetic signals.

Related Glossary Terms: Analog

Term Source: Chapter 1 – Early digital computational devices

Digital compositing

Compositing is the combining of visual elements from separate sources into single images, often to create the illusion that all those elements are parts of the same scene. Live-action shooting for compositing is variously called “chroma key”, “blue screen”, “green screen” and other names. Today, most, though not all, compositing is achieved through digital image manipulation. Pre-digital compositing techniques, however, go back as far as the trick films of Georges Méliès in the late 19th century; and some are still in use.

Related Glossary Terms:

Term Source:

Digital painting

Digital painting differs from other forms of digital art, particularly computer-generated art, in that it does not involve the computer rendering from a model. The artist uses painting techniques to create the digital painting directly on the computer. All digital painting programs try to mimic the use of physical media through various brushes and paint effects. Included in many programs are brushes that are digitally styled to represent the traditional style like oils, acrylics, pastels, charcoal, pen and even media such as airbrushing. There are also certain effects unique to each type of digital paint which portraying the realistic effects of say watercolor on a digital ‘watercolor’ painting

Related Glossary Terms:

Term Source: Chapter 11 – Pixar

Digital Scene Simulation

Digital Scene Simulation was Digital Productions’ philosophy for creating visual excellence in computer-generated imagery and simulation. The approach it advocated required the use of powerful hardware, sophisticated software, and top creative talent. With a CRAY supercomputer at the heart of its computer network

and its own proprietary image rendering and simulation software, Digital Productions was revolutionizing state-of-the-art computer graphics. At the forefront of computer graphics technology, Digital Productions was redefining traditional methods of visual communications and creating new forms of self-expression, instruction, and entertainment.

(From the Abstract of the invited paper “Digital scene simulations: The synergy of computer technology and human creativity”, by Demos, G.; Brown, M.D.; and Weinberg, R.A. Proceedings of the IEEE, Volume: 72 , Issue: 1, Jan. 1984, Page(s): 22 – 31)

Related Glossary Terms:

Term Source: Chapter 6 – Information International Inc. (Triple-I), Chapter 6 – Information International Inc. (Triple-I)

Digitize

1. to convert (data) to digital form for use in a computer.
2. to convert (analogous physical measurements) to digital form.

Related Glossary Terms: Digital

Term Source: Chapter 4 – MIT and Harvard

DOA

DOA == Digital/Omnibus/Abel

In about 1985, the Digital Productions board went along with a hostile takeover bid by Omnibus and their leader, John Pennie, breaking the agreement with partners John Whitney Jr. and Gary Demos. Later that same year, Omnibus also purchased Robert Abel and Associates. The huge amount of debt, much of it provided by the Royal Bank of Canada, proved to be a burden for the company, and they declared bankruptcy) only 9 months later on April 13th of 1987. The closure had significant rippling effects on the CG industry, and impacted the lives of many top-flight CG professionals.

Related Glossary Terms: Abel, Robert, Demos, Gary, Pennie, John

Term Source: Chapter 8 – Wavefront Technologies

Drum plotter

A graphics output device that draws lines with a continuously moving pen on a sheet of paper rolled around a rotating drum that moves the paper in a direction perpendicular to the motion of the pen.

Related Glossary Terms:

Term Source: Chapter 10 – MCS / CalComp / McAuto

Dynamics

In the field of physics, the study of the causes of motion and changes in motion is dynamics. In other words the study of forces and why objects are in motion. Dynamics includes the study of the effect of torques on motion. These are in contrast to kinematics, the branch of classical mechanics that describes the motion of objects without consideration of the causes leading to the motion.

Related Glossary Terms: Kinematics

Term Source: Chapter 8 – Introduction

E

Elin, Larry

Larry Elin started his career as an animator at Mathematical Applications Group, Inc., in Elmsford, NY, in 1973, one of the first 3-D computer animation companies. By 1980, Elin had become head of production, and hired Chris Wedge, who later founded Blue Sky Studios, among others. Elin and Wedge were the key animators on MAGI's work on the feature film Tron, which included the Lightcycle, Recognizer, and Tank sequences. Elin later became executive producer at Kroyer Films, which produced the animation for FernGully: The Last Rainforest.

Related Glossary Terms:

Term Source: Chapter 6 – MAGI

Ellipsoids

a geometric surface, symmetrical about the three coordinate axes, whose plane sections are ellipses or circles. Standard equation: x2/a2 + y2/b2 + z2/c2 = 1, where ±a, ±b, ±c are the intercepts on the x-, y-, and z- axes

Related Glossary Terms:

Term Source: Chapter 13 – Other Approaches

Em, David

David Em is one of the first artists to make art with pixels. He was born in Los Angeles and grew up in South America. He studied painting at the Pennsylvania Academy of the Fine Arts and film directing at the American Film Institute. Em created digital paintings at the Xerox Palo Alto Research Center (Xerox PARC) in 1975 with SuperPaint, “the first complete digital paint system”. In 1976, he made an articulated 3D digital insect at Information International, Inc. (III) that could walk, jump, and fly, the first 3D character created by a fine artist.

Related Glossary Terms:

Term Source: Chapter 9 – David Em

Emshwiller, Ed

Emshwiller was one of the earliest video artists. With Scape-Mates (1972), he began his experiments in video, combining computer animation with live-action. In 1979, he produced Sunstone, a groundbreaking three-minute 3-D computer-generated video made at the New York Institute of Technology with Alvy Ray Smith. Now in the Museum of Modern Art’s video collection, Sunstone was exhibited at SIGGRAPH 79, the 1981 Mill Valley Film Festival and other festivals. In 1979, it was shown on WNET’s Video/Film Review, and a single Sunstone frame was used on the front cover of Fundamentals of Interactive Computer Graphics, published in 1982 by Addison-Wesley

Related Glossary Terms:

Term Source: Chapter 9 – Ed Emshwiller

Engelbart, Douglas C.

Douglas Carl Engelbart (born January 30, 1925) is an American inventor, and an early computer and internet pioneer. He is best known for his work on the challenges of human– computer interaction, particularly while at his Augmentation Research Center Lab in SRI International, resulting in the invention of the computer mouse,[3] and the development of hypertext, networked computers, and precursors to graphical user interfaces.

Related Glossary Terms:

Term Source: Chapter 3 – Input devices

ENIAC

ENIAC stands for Electronic Numerical Integrator and Computer. It was a secret World War II military project carried out by John Mauchly, a 32-year-old professor at Penn’s Moore School of Electrical Engineering and John Presper Eckert Jr., a 24-year-old genius inventor and lab assistant. The challenge was to speed up the tedious mathematical calculations needed to produce artillery firing tables for the Army. ENIAC was not completed until after the war but it performed until 1955 at Aberdeen, Md. ENIAC was enormous. It contained 17,500 vacuum

tubes, linked by 500,000 soldered connections. It filled a 50-foot long basement room and weighed 30 tons. Today, a single microchip, no bigger than a fingernail, can do more than those 30 tons of hardware.

Related Glossary Terms:

Term Source: Chapter 2 – Programming and Artistry

Environment mapping

Environment mapping is a technique that simulates the results of ray-tracing. Because environment mapping is performed using texture mapping hardware, it can obtain global reflection and lighting results in real-time.

Environment mapping is essentially the process of pre-computing a texture map and then sampling texels from this texture during the rendering of a model. The texture map is a projection of 3D space to 2D space.

Related Glossary Terms: Reflection mapping

Term Source:

Euler operators

In mathematics, Euler operators are a small set of operators to create polygon meshes. They are closed and sufficient on the set of meshes, and they are invertible.

A “polygon mesh” can be thought of as a graph, with vertices, and with edges that connect these vertices. In addition to a graph, a mesh has also faces: Let the graph be drawn (“embedded”) in a two-dimensional plane, in such a way that the edges do not cross (which is possible only if the graph is a planar graph). Then the contiguous 2D regions on either side of each edge are the faces of the mesh.

Related Glossary Terms:

Term Source: Chapter 5 – Other labs and NSF

Evans, David

David Cannon Evans (February 24, 1924 – October 3, 1998) was the founder of the computer science department at the University of Utah and co-founder (with Ivan Sutherland) of Evans & Sutherland, a computer firm which is known as a pioneer in the domain of computer-generated imagery

Related Glossary Terms:

Term Source: Chapter 4 – University of Utah

F

Facial animation

Computer facial animation is primarily an area of computer graphics that encapsulates models and techniques for generating and animating images of the human head and face. Due to its subject and output type, it is also related to many other scientific and artistic fields from psychology to traditional animation. The importance of human faces in verbal and non-verbal communication and advances in computer graphics hardware and software have caused considerable scientific, technological, and artistic interests in computer facial animation.

Related Glossary Terms: Kinematics, Motion capture

Term Source: Chapter 8 – Alias/Wavefront

Farnsworth, Philo

Philo Taylor Farnsworth was an American inventor and television pioneer. Although he made many contributions that were crucial to the early development of all-electronic television, he is perhaps best known for inventing the first fully functional all-electronic image pickup device (video camera tube), the “image dissector”, the first fully functional and complete all-electronic television system, and for being the first person to demonstrate such a system to the public. Farnsworth developed a television system complete with receiver and camera, which he produced commercially in the firm of the Farnsworth Television and Radio Corporation, from 1938 to 1951.

Related Glossary Terms:

Term Source: Chapter 1 – Electronic devices

Fetter, William

William Fetter was a graphic designer for Boeing Aircraft Co. and in 1960, was credited with coining the phrase “Computer Graphics” to describe what he was doing at Boeing at the time.

Related Glossary Terms:

Term Source: Chapter 2 – Programming and Artistry

Film recorder

A Film Recorder is a graphical output device for transferring digital images to photographic film.

All film recorders typically work in the same manner. The image is fed from a host computer as a raster stream over a digital interface. A film recorder exposes film through various mechanisms; flying spot (early recorders; photographing a high resolution video monitor; electron beam recorder (Sony); a CRT scanning dot (Celco); focused beam of light from an LVT (Light Valve Technology) recorder; a scanning laser beam (ARRILASER); or recently, full-frame LCD array chips;

Related Glossary Terms: Optical printers

Term Source: Chapter 6 – Digital Effects

Finite Element Analysis

The finite element method (FEM) (its practical application often known as finite element analysis (FEA)) is a numerical technique for finding approximate solutions of partial differential equations (PDE) as well as integral equations. The solution approach is based either on eliminating the differential equation completely (steady state problems), or rendering the PDE into an approximating system of ordinary differential equations, which are then numerically integrated using standard techniques such as Euler's method, Runge- Kutta, etc.

Related Glossary Terms:

Term Source: Chapter 10 – SDRC / Unigraphics

Flicker

a visual sensation, often seen in a television or CRT image, produced by periodic fluctuations, often due to the rate of refreshing the image on the screen, in the brightness of light at a frequency below that covered by the persistence of vision

Related Glossary Terms: Cathode Ray Tube

Term Source: Chapter 3 – Other output devices

Floating point

A real number (that is, a number that can contain a fractional part). The following are floating-point numbers: 3.0, -111.5, 1⁄2, 3E-5 The last example is a computer shorthand for scientific notation. It means 3*10-5 (or 10 to the negative 5th power multiplied by 3).

The term floating point is derived from the fact that there is no fixed number of digits before and after the decimal point; that is, the decimal point can float. There are also representations in which the number of digits before and after the decimal point is set, called fixed-point representations. In general, floating-point representations are slower and less accurate than fixed-point representations, but they can handle a larger range of numbers.

Related Glossary Terms:

Term Source: Chapter 15 – Graphics Accelerators

Foonly F1

Foonly was the computer company formed by Dave Poole, who was one of the principal Super Foonly designers. The Foonly was to be a successor to the DEC PDP-10, and was to have been built (along with a new operating system) by the Super Foonly project at the Stanford Artificial Intelligence Laboratory (SAIL). The intention was to leapfrog from the old DEC timesharing system SAIL was then running to a new generation, bypassing TENEX which at that time was the ARPANET standard. ARPA funding for both the Super Foonly and the new operating system was cut in 1974. The design for Foonly contributed greatly to the design of the PDP-10 model KL10. One of the prototype models was built for Information International Incorporated (Triple-I) and was used to compute CG for TRON.

Related Glossary Terms:

Term Source: Chapter 6 – Information International Inc. (Triple-I)

Forced perspective

Forced perspective is a technique that employs optical illusion to make an object appear farther away, closer, larger or smaller than it actually is. It is used primarily in photography, filmmaking and architecture. It manipulates human visual perception through the use of scaled objects and the correlation between them and the vantage point of the spectator or camera.

Related Glossary Terms:

Term Source: Chapter 14 – CGI and Effects in Films and Music Videos

Foreshortening

Foreshortening occurs when an object appears compressed when seen from a particular viewpoint, and the effect of perspective causes distortion. Foreshortening is a particularly effective artistic device, used to give the impression of three-dimensional volume and create drama in a picture.

Foreshortening is most successful when accurately rendered on the picture plane to create the illusion of a figure in space.

Related Glossary Terms:

Term Source: Chapter 20 – CG Icons

Form factor

In radiative heat transfer, a form factor is the proportion of all that radiation which leaves surface A and strikes surface B.

In radiosity calculations, the “form factor” describes the fraction of energy which leaves one surface and arrives at a second surface. It takes into account the distance between the surfaces, computed as the distance between the center of each of the surfaces, and their orientation in space relative to each other, computed as the angle between each surface’s normal vector and a vector drawn from the center of one surface to the center of the other surface. It is a dimensionless quantity.

Related Glossary Terms: Radiosity

Term Source: Chapter 19 – Global Illumination

Fractal

A geometrical or physical structure having an irregular or fragmented shape at all scales of measurement between a greatest and smallest scale such that certain mathematical or physical properties of the structure, as the perimeter of a curve or the flow rate in a porous medium, behave as if the dimensions of the structure (fractal dimensions) are greater than the spatial dimensions.

A fractal is a rough or fragmented geometric shape that can be subdivided in parts, each of which is (at least approximately) a reduced-size copy of the whole. Fractals are generally self-similar and independent of scale, that is they have similar properties at all levels of magnification or across all times.

Related Glossary Terms:

Term Source: Chapter 19 – Noise functions and Fractals

Frame buffer

A frame buffer (or framebuffer) is a video output device that drives a video display from a memory buffer containing a complete frame of data.The information in the memory buffer typically consists of color values for every pixel (point that can be displayed) on the screen. Color values are commonly stored in 1-bit binary (monochrome), 4-bit palettized, 8-bit palettized, 16-bit high color and 24-bit true color formats. An additional alpha channel is sometimes used to retain information about pixel transparency. The total amount of the memory required to drive the frame buffer depends on the resolution of the output signal, and on the color depth and palette size.

Frame buffers differ significantly from the vector displays that were common prior to the advent of the frame buffer. With a vector display, only the vertices of the graphics primitives are stored. The electron beam of the

output display is then commanded to move from vertex to vertex, tracing an analog line across the area between these points. With a frame buffer, the electron beam (if the display technology uses one) is commanded to trace a left- to-right, top-to-bottom path across the entire screen, the way a television renders a broadcast signal. At the same time, the color information for each point on the screen is pulled from the frame buffer, creating a set of discrete picture elements (pixels).

Related Glossary Terms: A-buffer or Alpha-buffer

Term Source: Chapter 6 – Information International Inc. (Triple-I)

Frame-grabbing

A frame grabber is an electronic device that captures individual, digital still frames from an analog video signal or a digital video stream. It is usually employed as a component of a computer vision system, in which video frames are captured in digital form and then displayed, stored or transmitted in raw or compressed digital form. Historically, frame grabbers were the predominant way to interface cameras to PC’s

Related Glossary Terms:

Term Source: Chapter 16 – Amiga

Free-form surface

Free-form surface, or freeform surfacing, is used in CAD and other computer graphics software to describe the skin of a 3D geometric element. Freeform surfaces do not have rigid radial dimensions, unlike regular surfaces such as planes, cylinders and conic surfaces. They are used to describe forms such as turbine blades, car bodies and boat hulls. Initially developed for the automotive and aerospace industries, freeform surfacing is now widely used in all engineering design disciplines from consumer goods products to ships. Most systems today use nonuniform rational B-spline (NURBS) mathematics to describe the surface forms; however, there are other methods such as Gorden surfaces or Coons surfaces .

Related Glossary Terms: B-rep, Solids modeling

Term Source: Chapter 10 – Intergraph / Bentley / Dassault

Fuchs, Henry

Prof. Henry Fuchs is a fellow of the American Academy of Arts and Sciences (AAAS) and the Association for Computing Machinery (ACM) and the Federico Gill Professor of Computer Science at the University of North Carolina at Chapel Hill (UNC). He is also an adjunct professor in biomedical engineering. His research interests are in computer graphics, particularly rendering algorithms, hardware, virtual environments, telepresence systems,

and applications in medicine. In 1992, he received both the ACM SIGGRAPH Achievement Award and the Academic Award of the National Computer Graphics Association (NCGA)

Related Glossary Terms:

Term Source: Chapter 5 – UNC and Toronto

G

Gates, Bill

William Henry "Bill" Gates III is the former chief executive and current chairman of Microsoft, the world's largest personal-computer software company, which he co-founded with Paul Allen. He is consistently ranked among the world's wealthiest people. During his career at Microsoft, Gates held the positions of CEO and chief software architect, and remains the largest individual shareholder.

Related Glossary Terms:

Term Source: Chapter 16 – The IBM PC and Unix

Gehring, Bo

Bo Gehring was hired by Phil Mittleman of MAGI in 1972 to develop the division of the company focused on computer image making (MAGI Synthavision). He was the principle of Gehring Aviation and Bo Gehring Associates in Venice, California, and originally came to the west coast to do computer animation tests for Steven Spielberg's CLOSE ENCOUNTERS OF THE THIRD KIND.

Related Glossary Terms:

Term Source: Chapter 6 – Bo Gehring and Associates

Genlocking

Genlock (generator locking) is a common technique where the video output of one source, or a specific reference signal from a signal generator, is used to synchronize other television picture sources together. The aim in video applications is to ensure the coincidence of signals in time at a combining or switching point. When video instruments are synchronized in this way, they are said to be generator locked, or genlocked.

Related Glossary Terms:

Term Source: Chapter 16 – Amiga

Global illumination

Global illumination is a general name for a group of algorithms used in 3D computer graphics that are meant to add more realistic lighting to 3D scenes. Such algorithms take into account not only the light which comes directly from a light source (direct illumination), but also subsequent cases in which light rays from the same source are reflected by other surfaces in the scene, whether reflective or not (indirect illumination).

Related Glossary Terms:

Term Source: Chapter 19 – Global Illumination

Glyphs

A glyph (pronounced GLIHF ; from a Greek word meaning carving) is a graphic symbol that provides the appearance or form for a character . A glyph can be an alphabetic or numeric font or some other symbol that pictures an encoded character.

It is a particular graphical representation, in a particular typeface, of a grapheme, or sometimes several graphemes in combination (a composed glyph), or a part of a grapheme. It can also be a grapheme or grapheme-like unit of text, as found in natural language writing systems (scripts). It may be a letter, a numeral, a punctuation mark, or a pictographic or decorative symbol such as dingbats. A character or grapheme is an abstract unit of text, whereas a glyph is a graphical unit.

For example, the sequence ffi contains three characters, but can be represented by one glyph, the three characters being combined into a single unit known as a ligature. Conversely, some typewriters require the use of multiple glyphs to depict a single character (for example, two hyphens in place of an em-dash, or an overstruck apostrophe and period in place of an exclamation mark).

Related Glossary Terms:

Term Source: Chapter 16 – Xerox PARC

Gouraud shading

Gouraud shading, named after Henri Gouraud, is an interpolation method used in computer graphics to produce continuous shading of surfaces represented by polygon meshes. In practice, Gouraud shading is most often used to achieve continuous lighting on triangle surfaces by computing the lighting at the corners of each triangle and linearly interpolating the resulting colors for each pixel covered by the triangle. Gouraud first published the technique in 1971.

Related Glossary Terms: Continuous shading, Phong shading

Term Source: Chapter 14 – CGI and Effects in Films and Music Videos

Graphics acceleration

Graphics accelerators are a type of graphics hardware that contains its own processor to boost performance levels. These processors are specialized for computing graphical transformations, so they achieve better results than the general-purpose CPU used by the computer. In addition, they free up the computer's CPU to execute other commands while the graphics accelerator is handling graphics computations.

The popularity of graphical applications, and especially multimedia applications, has made graphics accelerators not only a common enhancement, but a necessity. Most computer manufacturers now bundle a graphics accelerator with their mid-range and high-end systems.

Related Glossary Terms:

Term Source: Chapter 13 – Evans and Sutherland, Chapter 15 – Graphics Accelerators

Graphics processing unit

A graphics processing unit or GPU (also occasionally called visual processing unit or VPU) is a specialized electronic circuit designed to rapidly manipulate and alter memory in such a way so as to accelerate the building of images in a frame buffer intended for output to a display.

Related Glossary Terms: Graphics acceleration

Term Source: Chapter 15 – Graphics Accelerators

Graphics tablet

A graphics tablet (or digitizing tablet , graphics pad , drawing tablet) is a computer input device that allows one to hand-draw images and graphics, similar to the way one draws images with a pencil and paper. These tablets may also be used to capture data of handwritten signatures.

A graphics tablet (also called pen pad) consists of a flat surface upon which the user may "draw" an image using an attached stylus, a pen-like drawing apparatus. The image generally does not appear on the tablet itself but, rather, is displayed on the computer monitor. Some tablets however, come as a functioning secondary computer screen that you can interact with directly using the stylus.

Related Glossary Terms:

Term Source: Chapter 3 – Input devices

Graphics workstation

A workstation is a high-end microcomputer designed for technical or scientific applications. Intended primarily to be used by one person at a time. It is commonly connected to a local area network and run multi-user operating systems.

Historically, workstations had offered higher performance than desktop computers, especially with respect to CPU and graphics, memory capacity, and multitasking capability. Graphics workstations are optimized for the visualization and manipulation of different types of complex data such as 3D mechanical design, engineering simulation (e.g. computational fluid dynamics), animation and rendering of images, and mathematical plots. Consoles consist of a high resolution display, a keyboard and a mouse at a minimum, but also offer multiple displays, graphics tablets, 3D mice (devices for manipulating 3D objects and navigating scenes), etc.

Related Glossary Terms:

Term Source: Chapter 15 – Apollo / Sun / SGI

Greenberg, Donald P.

Donald Peter Greenberg is the Jacob Gould Schurman Professor of Computer Graphics at Cornell University. He joined the Cornell faculty in 1968 with a joint appointment in the College of Engineering and College of Architecture. He currently serves as Director of the Program of Computer Graphics.

In 1971, Greenberg produced an early sophisticated computer graphics movie, Cornell in Perspective, using the General Electric Visual Simulation Laboratory. Greenberg also co- authored a series of papers on the Cornell Box.

An internationally recognized pioneer in computer graphics, Greenberg has authored hundreds of articles and served as a teacher and mentor to many prominent computer graphic artists and animators. Greenberg was the founding director of the National Science Foundation Science and Technology Center for Computer Graphics and Scientific Visualization when it was created in 1991.

Greenberg received the Steven Anson Coons Award in 1987, the most prestigious award in the field of computer graphics.

Related Glossary Terms:

Term Source: Chapter 5 – Cornell and NYIT

GUI (Graphical User Interface)

An interface for issuing commands to a computer utilizing a pointing device, such as a mouse, that manipulates and activates graphical images on a monitor.

Related Glossary Terms:

Term Source: Chapter 3 – Work continues at MIT, Chapter 16 – Xerox PARC

H

Haptic

Haptic technology, or haptics, is a tactile feedback technology which takes advantage of the sense of touch by applying forces, vibrations, or motions to the user. This mechanical stimulation can be used to assist in the creation of virtual objects in a computer simulation, to control such virtual objects, and to enhance the remote control of machines and devices (telerobotics). It has been described as “doing for the sense of touch what computer graphics does for vision”. Haptic devices may incorporate tactile sensors that measure forces exerted by the user on the interface.

Related Glossary Terms:

Term Source: Chapter 17 – Interaction

Hausdorff-Besicovich dimension

the Hausdorff dimension (also known as the Hausdorff–Besicovitch dimension) is an extended non-negative real number associated with a metric space. The Hausdorff dimension generalizes the notion of the dimension of a real vector space in that the Hausdorff dimension of an n-dimensional inner product space equals n. This means, for example, the Hausdorff dimension of a point is zero, the Hausdorff dimension of a line is one, and the Hausdorff dimension of the plane is two. There are, however, many irregular sets that have noninteger Hausdorff dimension. The concept was introduced in 1918 by the mathematician Felix Hausdorff. Many of the technical developments used to compute the Hausdorff dimension for highly irregular sets were obtained by Abram Samoilovitch Besicovitch.

Related Glossary Terms:

Term Source: Chapter 19 – Noise functions and Fractals

Head-mounted displays

A head-mounted display or helmet mounted display, both abbreviated HMD, is a display device, worn on the head or as part of a helmet, that has a small display optic in front of one (monocular HMD) or each eye (binocular HMD).

A typical HMD has either one or two small displays with lenses and semi-transparent mirrors embedded in a helmet, eye-glasses (also known as data glasses) or visor. The display units are miniaturized and may include CRT, LCDs, Liquid crystal on silicon (LCos), or OLED.

Related Glossary Terms: Stereoscopic display

Term Source: Chapter 17 – Virtual Reality

Heads-up display

A head-up display or heads-up display—also known as a HUD—is any transparent display that presents data without requiring users to look away from their usual viewpoints. The origin of the name stems from a pilot being able to view information with the head positioned “up” and looking forward, instead of angled down looking at lower instruments.

Although they were initially developed for military aviation, HUDs are now used in commercial aircraft, automobiles, and other applications.

Related Glossary Terms:

Term Source: Chapter 17 – Interaction

Height maps

In computer graphics, a height map or height field is a raster image used to store values, such as surface elevation data, for display in 3D computer graphics. A height map can be used in bump mapping to calculate where this 3D data would create shadow in a material, in displacement mapping to displace the actual geometric position of points over the textured surface, or for terrain where the height map is converted into a 3D mesh.

Related Glossary Terms:

Term Source: Chapter 13 – Other Approaches

Hidden line elimination

Hidden line elimination is an extension of wireframe model rendering where lines (or segments of lines) covered by surfaces of a model are not drawn, resulting in a more accurate representation of a 3D object.

Related Glossary Terms: Hidden surfaces

Term Source:

Hidden surfaces

In 3D computer graphics, hidden surface determination (also known as hidden surface removal (HSR), occlusion

culling (OC) or visible surface determination (VSD)) is the process used to determine which surfaces and parts of surfaces are not visible from a certain viewpoint. A hidden surface determination algorithm is a solution to the visibility problem, which was one of the first major problems in the field of 3D computer graphics.

Related Glossary Terms: Hidden line elimination

Term Source: Chapter 17 – Virtual Reality

Hopper, Grace

Rear Admiral Grace Murray Hopper was an American computer scientist and United States Navy officer. A pioneer in the field, she was one of the first programmers of the Harvard Mark I computer, and developed the first compiler for a computer programming language. She conceptualized the idea of machine-independent programming languages, which led to the development of COBOL, one of the first modern programming languages. She is credited with popularizing the term “debugging” for fixing computer glitches (motivated by an actual moth removed from the computer).

Related Glossary Terms:

Term Source: Chapter 2 – Programming and Artistry

I

I&D architectures

I&D (instructions and data) – refers to the ability to address instructions and data in the same computer “word”

Related Glossary Terms:

Term Source: Chapter 3 – TX-2 and DEC

Image processing

In imaging science, image processing is any form of signal processing for which the input is an image, such as a photograph or video frame; the output of image processing may be either an image or a set of characteristics or parameters related to the image. Most image- processing techniques involve treating the image as a two-dimensional signal and applying standard signal-processing techniques to it.

Related Glossary Terms:

Term Source: Chapter 13 – NASA

Imax

IMAX is a motion picture film format and a set of proprietary cinema projection standards created by the Canadian company IMAX Corporation. IMAX has the capacity to record and display images of far greater size and resolution than conventional film systems.

Related Glossary Terms:

Term Source:

Chapter 11 – Sogitec Audiovisuel

Ink and paint

Digital ink-and-paint is the computerized version of finalizing animation art using scanning, instead of inking, for each pencil drawing, and digitally coloring instead of hand-painting each cel. With all the ink-and-paint programs now available it is possible to drop fill (single- click paint an entire enclosed area) or use a digital paintbrush to fill colors into characters.

Related Glossary Terms:

Term Source: Chapter 11 – Metrolight / Rezn8

Integrated circuit

A circuit of transistors, resistors, and capacitors constructed on a single semiconductor wafer or chip, in which the components are interconnected to perform a given function. Abbreviation: IC

Related Glossary Terms:

Term Source: Chapter 1 – Electronic devices

Interpolation

Linear interpolation, in computer graphics often called “LERP” (Linear interpolation), is a very (if not the simplest) method of interpolation.

For a set of discrete values linear interpolation can approximate other values in between, assuming a linear development between these discrete values. An interpolated value, calculated with linear interpolation, is calculated only in respect to the two surrounding values, which makes it a quite inappropriate choice if the desired curve should be smooth. If a curvier interpolation is needed, cubic interpolation or splines might be an option.

Linear interpolation is the simplest method of getting values at positions in between the data points. The points are simply joined by straight line segments.

Cubic interpolation is the simplest method that offers true continuity between segments. As such it requires more than just the two endpoints of the segment but also the two points on either side of them. So the function requires 4 points in all.

Related Glossary Terms:

Term Source: Chapter 8 – Introduction

Isolines

An isoline (also contour line, isopleth, or isarithm) of a function of two variables is a curve along which the function has a constant value. For example, in cartography, a contour line (often just called a “contour”) joins points of equal elevation (height) above a given level, such as mean sea level.[A contour map is a map illustrated with contour lines, for example a topographic map, which thus shows valleys and hills, and the steepness of slopes. The contour interval of a contour map is the difference in elevation between successive contour lines.

Related Glossary Terms: Isosurfaces

Term Source: Chapter 18 – Introduction

Isosurfaces

An isosurface is a three-dimensional analog of an isoline. It is a surface that represents points of a constant value (e.g. pressure, temperature, velocity, density) within a volume of space; in other words, it is a level set of a continuous function whose domain is 3D-space.

Related Glossary Terms: Contour plots, Isolines

Term Source: Chapter 18 – Introduction

Iterated function systems

In mathematics, iterated function systems or IFSs are a method of constructing fractals; the resulting constructions are always self-similar.

IFS is the term originally devised by Michael Barnsley and Steven Demko for a collection of contraction mappings over a complete metric space, typically compact subsets of Rn . The landmark papers of John Hutchinson and, independently, Barnsley and Demko showed how such systems of mappings with associated

probabilities could be used to construct fractal sets and measures: the former from a geometric measure theory setting and the latter from a probabilistic setting.

http://links.uwaterloo.ca/ResearchIFSFractalCoding.html

Related Glossary Terms:

Term Source: Chapter 19 – Plants

J

Jaggies

Jaggies" is the informal name for artifacts in raster images, most frequently from aliasing,[1] which in turn is often caused by non-linear mixing effects producing high-frequency components and/or missing or poor anti-aliasing filtering prior to sampling.

Jaggies are stair like lines that appear where there should be smooth straight lines or curves. For example, when a nominally straight, un-aliased line steps across one pixel, a dogleg occurs halfway through the line, where it crosses the threshold from one pixel to the other.

Related Glossary Terms: Antialiasing

Term Source: Chapter 15 – Graphics Accelerators

Jobs, Steve

Steven Paul "Steve" Jobs was an American entrepreneur who is best known as the co- founder, chairman, and chief executive officer of Apple Inc. Through Apple, he was widely recognized as a charismatic pioneer of the personal computer revolution and for his influential career in the computer and consumer electronics fields. Jobs also co-founded and served as chief executive of Pixar Animation Studios; he became a member of the board of directors of The Walt Disney Company in 2006, when Disney acquired Pixar.

Related Glossary Terms:

Term Source: Chapter 16 – Apple Computer

K

Kajiya, Jim

Jim Kajiya is a pioneer in the field of computer graphics. He is perhaps best known for the development of the rendering equation.Kajiya received his PhD from the University of Utah in 1979, was a professor at Caltech from 1979 through 1994, and is currently a researcher at Microsoft Research.

Related Glossary Terms:

Term Source: Chapter 5 – Cal Tech and North Carolina State, Chapter 19 – Global Illumination

Kawaguchi, Yoichiro

Yoichiro Kawaguchi is a Japanese computer graphics artist, professor at the University of Tokyo. Kawaguchi rose to international prominence in 1982 when he presented “Growth Model” in the international conference SIGGRAPH.

Related Glossary Terms:

Term Source: Chapter 9 – Yoichiro Kawaguchi

Keyframe

A key frame in animation and filmmaking is a drawing that defines the starting and ending points of any smooth transition. They are called “frames” because their position in time is measured in frames on a strip of film. A sequence of keyframes defines which movement the viewer will see, whereas the position of the keyframes on the film, video or animation defines the timing of the movement. Because only two or three keyframes over the span of a second do not create the illusion of movement, the remaining frames are filled with in- betweens.

Related Glossary Terms:

Term Source: Chapter 4 – University of Utah, Chapter 4 – The Ohio State University, Chapter 4 – JPL and National Research Council of Canada

Kinematics

Forward kinematic animation is a method in 3D computer graphics for animating models.

The essential concept of forward kinematic animation is that the positions of particular parts of the model at a specified time are calculated from the position and orientation of the object, together with any information on the joints of an articulated model. So for example if the object to be animated is an arm with the shoulder remaining at a fixed location, the location of the tip of the thumb would be calculated from the angles of the shoulder, elbow, wrist, thumb and knuckle joints. Three of these joints (the shoulder, wrist and the base of the thumb) have more than one degree of freedom, all of which must be taken into account. If the model were an entire human figure, then the location of the shoulder would also have to be calculated from other properties of the model.

Forward kinematic animation can be distinguished from inverse kinematic animation by this means of calculation – in inverse kinematics the orientation of articulated parts is calculated from the desired position of certain points on the model. It is also distinguished from other animation systems by the fact that the motion of the model is defined directly by the animator – no account is taken of any physical laws that might be in effect on the model, such as gravity or collision with other models.

Related Glossary Terms: Dynamics

Term Source: Chapter 8 – Introduction

Kinetic Art

Kinetic art is art that contains moving parts or depends on motion for its effect. The moving parts are generally powered by wind, a motor or the observer. Kinetic art encompasses a wide variety of overlapping techniques and styles.

Related Glossary Terms:

Term Source: Chapter 9 – Vera Molnar

Kleiser, Jeff

Jeff Kleiser is widely recognized as a leader in animation and visual effects. He has produced and directed visual effects for numerous award-winning television commercials, and has created unique location-based entertainment projects such as the 3D stereoscopic films Corkscrew Hill (for Bush Gardens), Santa Lights up New York (for Radio City Music Hall), and The Amazing Adventures of Spider-Man (for Universal Studios). Kleiser's film credits range from Walt Disney's Tron, the ground-breaking CGI movie released to critical acclaim in 1982, to recent Hollywood releases such as X-Men (including X-Men 2 and X- Men: The Last Stand), Fantastic Four, Scary Movie (3 and 4), Slither, Son of the Mask, Exorcist: The Beginning, and many more. In 1987 Kleiser and partner Diana Walczak founded the visual effects studio Kleiser-Walczak and together coined the term "synthespian" to describe digital actors (synthetic thespians). In 2005 Kleiser and Walczak founded Synthespian Studios (synthespians.net) to create original projects for animated characters.

Related Glossary Terms:

Term Source: Chapter 6 – Digital Effects

Kodalith

A high contrast black and white film made by Kodak, used also as a special effect film in the darkroom (allowed for the recording ultra high contrast images)

Related Glossary Terms:

Term Source: Chapter 2 – Programming and Artistry

Kovacs, Bill

Bill Kovacs received a Bachelor of Architecture degree from Carnegie Mellon University in 1971. He worked for Skidmore, Owings and Merrill (New York office) while getting a Masters of Environmental Design from Yale University (1972). He was then transferred to the Chicago Office, where he worked on a computer-aided design system.

In 1978, Kovacs left SOM to become VP of R&D for the early computer animation company Robert Abel and Associates (1978-1984). At Abel, Kovacs (along with Roy Hall and others) developed the company's animation software. Kovacs used this software, with others in the film Tron. He later co-founded Wavefront Technologies as CTO (1984-1994), leading the development of products such as The Advanced Visualizer as well as animated productions. Along with Richard Childers and Chris Baker, he was a key organizer of the Infinite Illusions at the Smithsonian Institution exhibit in 1991.

Following retirement from Wavefront, Kovacs co-founded Instant Effects, worked as a consultant to Electronic Arts and RezN8, serving as RezN8's CTO from 2000 until his death. In 1998, Kovacs received a 1997 (Scientific and Engineering) Academy Award from the Academy of Motion Picture Arts and Sciences. In 1980, he received two Clio Awards for his work on animated TV commercials.

Related Glossary Terms:

Term Source: Chapter 6 – Robert Abel and Associates

Kristoff, Jim

President of Cranston/Csuri Productions, and founder of Metrolight Productions in Los Angeles.

Related Glossary Terms:

Term Source: Chapter 6 – Cranston/Csuri Productions

Krueger, Myron

Myron Krueger is an American computer artist who developed early interactive works. He is also considered to be one of the first generation virtual reality and augmented reality researchers. He earned a Ph.D. in Computer Science at the University of Wisconsin– Madison and in 1969, he collaborated with Dan Sandin, Jerry Erdman and Richard Venezky on a computer controlled environment called "glowflow," a computer-controlled light sound environment that responded to the people within it. Krueger went on to develop Metaplay, an integration of

visuals, sounds, and responsive techniques into a single framework. A later project, “Videoplace,” was funded by the National Endowment for the arts and a two- way exhibit was shown at the Milwaukee Art Museum in 1975. From 1974 to 1978 Krueger performed computer graphics research at the Space Science and Engineering Center of the University of Wisconsin–Madison in exchange for institutional support for his “Videoplace” work. In 1978, joined the computer science faculty at the University of Connecticut, where he taught courses in hardware, software, computer graphics and artificial intelligence.

Related Glossary Terms:

Term Source: Chapter 17 – Hypermedia and Art

L

L-systems

An L-system or Lindenmayer system, is a parallel rewriting system, namely a variant of a formal grammar, most famously used to model the growth processes of plant development, but also able to model the morphology of a variety of organisms. An L-system consists of an alphabet of symbols that can be used to make strings, a collection of production rules which expand each symbol into some larger string of symbols, an initial “axiom” string from which to begin construction, and a mechanism for translating the generated strings into geometric structures. L-systems can also be used to generate self-similar fractals such as iterated function systems.

Related Glossary Terms:

Term Source: Chapter 19 – Plants

Lambertian

If a surface exhibits Lambertian reflectance, light falling on it is scattered such that the apparent brightness of the surface to an observer is the same regardless of the observer’s angle of view. More technically, the surface luminance is isotropic. For example, unfinished wood exhibits roughly Lambertian reflectance, but wood finished with a glossy coat of polyurethane does not, since specular highlights may appear at different locations on the surface. Not all rough surfaces are perfect Lambertian reflectors, but this is often a good approximation when the characteristics of the surface are unknown. Lambertian reflectance is named after Johann Heinrich Lambert.

In computer graphics, Lambertian reflection is often used as a model for diffuse reflection. This technique causes all closed polygons (such as a triangle within a 3D mesh) to reflect light equally in all directions when rendered.

Related Glossary Terms: Diffuse reflection, Specular reflection

Term Source: Chapter 19 – Global Illumination

Langlois, Daniel

Daniel Langlois is the president and founder of the Daniel Langlois Foundation, Ex-Centris, and Media Principia Inc. He also founded Softimage Inc., serving as its president and chief technology officer from November 1986 to July 1998. The company is recognized in the fields of cinema and media creation for its digital technologies and especially its 3-D computer animation techniques. Softimage software was used to create most of the 3-D effects in the movies Star Wars Episode I: The Phantom Menace, The Matrix, Titanic, Men in Black, Twister, Jurassic Park, The Mask and The City of Lost Children.

Related Glossary Terms:

Term Source: Chapter 8 – SoftImage

Laposky, Ben

Ben Laposky was a mathematician and artist from Iowa. In 1950, he created the first graphic images generated by an electronic (in his case, an analog) machine.

Related Glossary Terms:

Term Source: Chapter 2 – Programming and Artistry

Lasseter, John

John Alan Lasseter is an American animator, film director and the chief creative officer at Pixar and Walt Disney Animation Studios. He is also currently the Principal Creative Advisor for Walt Disney Imagineering. Lasseter's first job was with The Walt Disney Company, where he became an animator. Next, he joined Lucasfilm, where he worked on the then- groundbreaking use of CGI animation. After the Graphics Group of the Computer Division of Lucasfilm was sold to Steve Jobs and became Pixar in 1986, Lasseter oversaw all of Pixar's films and associated projects as executive producer and he directed Toy Story, A Bug's Life, Toy Story 2, Cars, and Cars 2.

He has won two Academy Awards, for Animated Short Film (for Tin Toy), as well as a Special Achievement Award (for Toy Story).

Related Glossary Terms:

Term Source: Chapter 6 – MAGI

Light pen

a rodlike device which, when focused on the screen of a cathode-ray tube, can detect the time of passage of the

illuminated spot across that point thus enabling a computer to determine the position on the screen being pointed at

Related Glossary Terms: Cathode Ray Tube

Term Source: Chapter 3 – General Motors DAC, Chapter 3 – Input devices

Lofting

The creation of a 3D surface model by joining adjacent cross-sectional data with surface elements, such as triangles.

Related Glossary Terms:

Term Source: Chapter 18 – Algorithms

Lytle, Wayne

Wayne Lytle is the founder of Animusic, an American musical computer animation company. In 1988, he joined the Cornell Theory Center, where he could experiment with his idea as a scientific visualization producer. He created the piece More Bells & Whistles at Cornell in 1990 and composed Beyond The Walls in 1996. Lytle founded Animusic (originally under the name Visual Music) in 1995 with his associate David Crognale.

Related Glossary Terms:

Term Source: Chapter 19 – Data-driven Imagery

M

Machover, Carl

Carl Machover,a computer graphics pioneer and graphics “evangelist” is president of Machover Associates Corp (MAC), a computer graphics consultancy he founded in 1976,which provides a broad range of management, engineering, marketing, and financial services worldwide to computer graphics users, suppliers, and investors. Machover is also an Adjunct Professor at RPI, president of ASCI, past-president of NCGA, SID, and Computer Graphics Pioneers, on the editorial boards of many industry publications, writes and lectures world-wide on all aspects of computer graphics, and was guest editor of special computer graphics art issues of Computer and Graphics and the IEEE Computer Graphics and Applications, Machover received the North Carolina State University, Orthogonal Award , the NCGA Vanguard Award, .and was was inducted into the FAMLI Computer Graphics Hall of Fame. Machover passed away in 2012.

Related Glossary Terms:

Term Source: Chapter 6 – MAGI

Mandelbrot, Benoit

Benoît B. Mandelbrot was a French American mathematician. Born in Poland, he moved to France with his family when he was a child. Mandelbrot spent much of his life living and working at IBM in the United States, where he worked on a wide range of mathematical problems, including mathematical physics and quantitative finance. He is best known as the father of fractal geometry. He coined the term fractal and described the Mandelbrot set.

Related Glossary Terms:

Term Source: Chapter 19 – Noise functions and Fractals

Marks, Harry

Harry Marks is considered by many to be the founding father of modern broadcast design. He began his career as a typographer and publications designer at Oxford University Press. In the mid-1960s, he moved to Los Angeles and landed a job at ABC-TV, where his assignment was to improve the on-air graphic appearance of the network. He is also known for his work as an independent graphics consultant, including six years of on-air graphics for NBC-TV, brand packaging for international TV networks, and an Emmy-winning main title for Entertainment Tonight. Harry is well known for his innovative use of emerging technologies, such as computer graphics and slit scan. He has earned nearly every award in broadcast design and promotion, including an Emmy and the first Lifetime Achievement Award from the Broadcast Design Association. In 1984, Harry had the notion of facilitating a gathering of people from the converging worlds of technology, entertainment, and design, so he partnered with Richard Saul Wurman and created the TED Conference.

Related Glossary Terms:

Term Source: Chapter 6 – Pacific Data Images, Chapter 6 – Robert Abel and Associates

Max, Nelson

Max’s research interests are in the areas of scientific visualization, computer animation, and realistic computer graphics rendering. In visualization he works on molecular graphics, and volume and flow visualization, particularly on irregular finite element meshes. He has rendered realistic lighting effects in clouds, trees, and water waves, and has produced numerous computer animations, shown at the annual SIGGRAPH conferences, and in Omnimax at the Fujitu Pavilions at Expo ’85 in Tsukuba Japan, and Expo ’90 in Osaka Japan. His early work was done at Lawrence Livermore and he is currently affiliated with UC-Davis.

Related Glossary Terms:

Term Source: Chapter 4 – Bell Labs and Lawrence Livermore

Metaballs

Metaballs are, in computer graphics, organic-looking n-dimensional objects. The technique for rendering metaballs was invented by Jim Blinn in the early 1980s. Each metaball is defined as a function in n-dimensions.

Related Glossary Terms:

Term Source: Chapter 8 – Side Effects, Chapter 9 – Yoichiro Kawaguchi

MIP mapping

In 3D computer graphics texture filtering, mipmaps (also MIP maps) are pre-calculated, optimized collections of images that accompany a main texture, intended to increase rendering speed and reduce aliasing artifacts. They are widely used in 3D computer games, flight simulators and other 3D imaging systems. Mipmapping was invented by Lance Williams in 1983 and is described in his paper Pyramidal parametrics.

Related Glossary Terms:

Term Source:

Modular visualization environments

several systems have been developed around the concepts of applying visual languages to visualization application building; decomposing a visualization application into separable process (such as data analysis, geometric representation, and rendering); and finally creating a real-time development environment where applications are created interactively. These systems have given rise to disposable applications by utilizing reusable visualization and graphics algorithms. These techniques can be connected in a visual manner to create problem-targeted applications with a short lifetime, which dramatically reduces the time devoted to problem solving.

Because of their focus, these systems blur the distinction between program visualization (the process of dynamically viewing the execution ordering of a program), visualization programming (creating visualization applications using graphics libraries), and visualization prototyping (building visualization applications interactively).

Related Glossary Terms: Dataflow

Term Source: Chapter 18 – Visualization Systems

Monte Carlo method

Monte Carlo methods (or Monte Carlo experiments) are a class of computational algorithms that rely on repeated random sampling to compute their results. Monte Carlo methods are often used in computer simulations of physical and mathematical systems. These methods are most suited to calculation by a computer and tend to be used when it is infeasible to compute an exact result with a deterministic algorithm. This method is also used to complement theoretical derivations.

Monte Carlo methods are especially useful for simulating systems with many coupled degrees of freedom, such as fluids, disordered materials, strongly coupled solids, and cellular structures (see cellular Potts model). They are used to model phenomena with significant uncertainty in inputs, such as the calculation of risk in business. They are widely used in mathematics, for example to evaluate multidimensional definite integrals with complicated boundary conditions. When Monte Carlo simulations have been applied in space exploration and oil exploration, their predictions of failures, cost overruns and schedule overruns are routinely better than human intuition or alternative “soft” methods.

The Monte Carlo method was coined in the 1940s by John von Neumann, Stanislaw Ulam and Nicholas Metropolis, while they were working on nuclear weapon projects (Manhattan Project) in the Los Alamos National Laboratory.

Related Glossary Terms:

Term Source: Chapter 19 – Global Illumination

MOOG synthesizer

Moog synthesizer refers to any number of analog synthesizers designed by Dr. Robert Moog or manufactured by Moog Music, and is commonly used as a generic term for older- generation analog music synthesizers.

Related Glossary Terms: Sandin, Dan

Term Source: Chapter 5 – Illinois-Chicago and University of Pennsylvania

Morphing

Morphing is a special effect in motion pictures and animations that changes (or morphs) one image into another through a seamless transition. Most often it is used to depict one person turning into another through technological means or as part of a fantasy or surreal sequence. Traditionally such a depiction would be achieved through cross-fading techniques on film. Since the early 1990s, this has been replaced by computer software to create more realistic transitions.

Related Glossary Terms:

Term Source: Chapter 4 – University of Utah, Chapter 4 – The Ohio State University

Motion blur

Motion blur is the apparent streaking of rapidly moving objects in a still image or a sequence of images such as a movie or animation. It results when the image being recorded changes during the recording of a single frame, either due to rapid movement or long exposure.

In computer animation (2D or 3D) it is computer simulation in time and/or on each frame that the 3D rendering/ animation is being made with real video camera during its fast motion or fast motion of “cinematized” objects or to make it look more natural or smoother.

Related Glossary Terms:

Term Source: Chapter 19 – Noise functions and Fractals

Motion blur

Motion blur is the apparent streaking of rapidly moving objects in a still image or a sequence of images such as a movie or animation. It results when the image being recorded changes during the recording of a single exposure, either due to rapid movement or long exposure.

Related Glossary Terms:

Term Source: Chapter 11 – ILM

Motion capture

Motion capture, or mocap, is a technique of digitally recording movements for entertainment, sports and medical applications. It started as an analysis tool in biomechanics research, but has grown increasingly important as a source of motion data for computer animation as well as education, training and sports and recently for both cinema and video games. A performer wears a set of one type of marker at each joint: acoustic, inertial, LED, magnetic or reflective markers, or combinations, to identify the motion of the joints of the body. Sensors track the position or angles of the markers, optimally at least two times the rate of the desired motion. The motion capture computer program records the positions, angles, velocities, accelerations and impulses, providing an accurate digital representation of the motion.

Related Glossary Terms: Performance animation

Term Source: Chapter 4 – University of Utah

Mouse

Computers . a palm-sized, button-operated pointing device that can be used to move, select, activate, and change items on a computer screen.

Related Glossary Terms:

Term Source: Chapter 3 – Input devices

Multi-texturing

Texture mapping is a method for adding detail, surface texture (a bitmap or raster image), or color to a computer-generated graphic or 3D model. Its application to 3D graphics was pioneered by Dr Edwin Catmull in his Ph.D. thesis of 1974. Multitexturing is the use of more than one texture at a time on a polygon. For instance, a light map texture may be used to light a surface as an alternative to recalculating that lighting every time the surface is rendered. Another multitexture technique is bump mapping, which allows a texture to directly control the facing direction of a surface for the purposes of its lighting calculations; it can give a very good appearance of a complex surface, such as tree bark or rough concrete.

Related Glossary Terms: Texture Mapping

Term Source:

Multitasking

In computing, multitasking is a method where multiple tasks, also known as processes, are performed during the same period of time.

Related Glossary Terms:

Term Source: Chapter 16 – Apple Computer

Multivariate data

Data collected on several variables for each sampling unit. For example, if we collect information on weight (w), height (h), and shoe size (s) from each of a random sample of individuals, then we would refer to the triples (w1, h1, s1), (w2, h2, s2),…as a set of multivariate data.

Related Glossary Terms:

Term Source: Chapter 18 – Algorithms

N

Noise functions

Perlin noise is a procedural texture primitive, a type of gradient noise used by visual effects artists to increase the appearance of realism in computer graphics. The function has a pseudo-random appearance, yet all of its visual details are the same size (see image). This property allows it to be readily controllable; multiple scaled copies of Perlin noise can be inserted into mathematical expressions to create a great variety of procedural textures. Synthetic textures using Perlin noise are often used in CGI to make computer-generated visual elements – such as fire, smoke, or clouds – appear more natural, by imitating the controlled random appearance of textures of nature.

Noise functions are also frequently used to generate textures when memory is extremely limited, such as in demos, and is increasingly finding use in Graphics Processing Units for real-time graphics in computer games.

Related Glossary Terms: Fractal, Procedural rendering

Term Source: Chapter 6 – MAGI, Chapter 19 – Noise functions and Fractals

Numerical-control

A control system in which numerical values corresponding to desired tool or control positions are generated by a computer. Abbreviated CNC. Also known as computational numerical control; soft-wired numerical control; stored-program numerical control

Related Glossary Terms:

Term Source: Chapter 10 – MCS / CalComp / McAuto

NURBS

Non-uniform rational basis spline (NURBS) is a mathematical model commonly used in computer graphics for generating and representing curves and surfaces which offers great flexibility and precision for handling both analytic (surfaces defined by common mathematical formulae) and modeled shapes.

Related Glossary Terms:

Term Source: Chapter 8 – Alias Research

O

Object-oriented programming

Object-oriented programming (OOP) is a programming paradigm using “objects” – data structures consisting of data fields and methods together with their interactions – to design applications and computer programs. Programming techniques may include features such as data abstraction, encapsulation, messaging, modularity, polymorphism, and inheritance.

Related Glossary Terms:

Term Source: Chapter 16 – Apple Computer

Olsen, Ken

Kenneth Harry Olsen was an American engineer who co-founded Digital Equipment Corporation (DEC) in 1957 with colleague Harlan Anderson.

Related Glossary Terms:

Term Source: Chapter 3 – TX-2 and DEC

Omnimax

A variation of the IMAX film format that is projected on an angled dome

Related Glossary Terms:

Term Source: Chapter 5 – Cal Tech and North Carolina State

Op-art

Op art, also known as optical art, is a style of visual art that makes use of optical illusions.

Related Glossary Terms:

Term Source: Chapter 9 – Vera Molnar

Operating system

the collection of software that directs a computer’s operations, controlling and scheduling the execution of other programs, and managing storage, input/output, and communication resources. Abbreviation: OS

Related Glossary Terms:

Term Source: Chapter 3 – TX-2 and DEC

Optical printers

An optical printer is a device consisting of one or more film projectors mechanically linked to a movie camera. It allows filmmakers to re-photograph one or more strips of film. The optical printer is used for making special effects for motion pictures, or for copying and restoring old film material.

Common optical effects include fade outs and fade ins, dissolves, slow motion, fast motion, and matte work. More complicated work can involve dozens of elements, all combined into a single scene.

Related Glossary Terms: Film recorder

Term Source: Chapter 6 – Robert Abel and Associates

Orthographic

Orthographic projection (or orthogonal projection) is a means of representing a three- dimensional object in two dimensions. It is a form of parallel projection, where all the projection lines are orthogonal to the projection plane, resulting in every plane of the scene appearing in affine transformation on the viewing surface. It is further divided into multi- view orthographic projections and axonometric projections. A lens providing an orthographic projection is known as an (object-space) tele-centric lens.

Related Glossary Terms:

Term Source: Chapter 4 – Bell Labs and Lawrence Livermore

Oxberry animation camera

An animation camera, a type of rostrum camera, is a movie camera specially adapted for frame-by-frame shooting animation or stop motion. It consists of a camera body with lens and film magazines, a stand that allows the camera to be raised and lowered, and a table, often with both top and underneath lighting. The artwork to be photographed is placed on this table. The Oxberry was made by Oxberry LLC in New Jersey.

Related Glossary Terms:

Term Source: Chapter 11 – Sogitec Audiovisuel

P

Paged architecture

In paging, the memory address space is divided into equal, small pieces, called pages. Using a virtual memory mechanism, each page can be made to reside in any location of the physical memory, or be flagged as being protected. Virtual memory makes it possible to have a linear virtual memory address space and to use it to access blocks fragmented over physical memory address space.

Related Glossary Terms:

Term Source Chapter 3 – TX-2 and DEC

Parametric modeling

Parametric modeling uses parameters to define a model (dimensions, for example). Examples of parameters are: dimensions used to create model features, material density, formulas to describe swept features, imported data (that describe a reference surface, for example). The parameter may be modified later, and the model will update to reflect the modification.

Related Glossary Terms:

Term Source: Chapter 10 – SDRC / Unigraphics

Particle system

The term particle system refers to a computer graphics technique to simulate certain fuzzy phenomena, which are otherwise very hard to reproduce with conventional rendering techniques. Examples of such phenomena which are commonly replicated using particle systems include fire, explosions, smoke, moving water, sparks, falling leaves, clouds, fog, snow, dust, meteor tails, hair, fur, grass, or abstract visual effects like glowing trails, magic spells, etc.

Related Glossary Terms:

Term Source: Chapter 4 – University of Utah, Chapter 4 – The Ohio State University

Patch panel

A panel of electronic ports contained together that connects incoming and outgoing lines of a LAN or other communication, sound, electronic or electrical system. Connections are made with patch cords. The patch panel allows circuits to be arranged and rearranged by plugging and unplugging the patch cords.

Related Glossary Terms:

Term Source: Chapter 12 – ANIMAC / SCANIMATE

Pennie, John

President of Omnibus

Related Glossary Terms: DOA

Term Source: Chapter 6 – Omnibus Computer Graphics

Performance animation

Performance animation could be described as ‘improvisation meets CG (computer graphics). This involves providing real-time rendered 3D animated characters that are doing the same movements as actors, at the same time. The 3D character(s) can exist within a computer generated ‘virtual set’ or can interact with human characters in a real environment (often seen in dance performances) or human characters in a virtual environment.

Related Glossary Terms: Motion capture

Term Source: Chapter 6 – Pacific Data Images (PDI)

Perlin, Ken

Ken Perlin is a professor at New York University, founding director of the Media Research Lab at NYU, and the Director of the Games for Learning Institute. He developed or was involved with the development of techniques such as Perlin noise, hypertexture, real-time interactive character animation, and computer-user interfaces such as zooming user interfaces, stylus-based input, and most recently, cheap, accurate multi-touch input devices. He is also the Chief Technology Advisor of ActorMachine, LLC. His invention of Perlin noise in 1985 has become a standard that is used in both computer graphics and movement.

Perlin was founding director of the NYU Media Research Laboratory and also directed the NYU Center for Advanced Technology from 1994 to 2004. He was the System Architect for computer generated animation at Mathematical Applications Group, Inc. 1979-1984, where he worked on Tron.

Related Glossary Terms:

Term Source: Chapter 19 – Noise functions and Fractals

Perspective (or Perspective Projection)

Perspective projection is a type of drawing that graphically approximates on a planar (two-dimensional) surface (e.g. computer display) the images of three-dimensional objects so as to approximate actual visual perception. It is sometimes also called perspective view or perspective drawing or simply perspective.

Related Glossary Terms:

Term Source:

Phong shading

Phong shading refers to an interpolation technique for surface shading in 3D computer graphics. It is also called Phong interpolation or normal-vector interpolation shading. Specifically, it interpolates surface normals across rasterized polygons and computes pixel colors based on the interpolated normals and a reflection model. Phong shading may also refer to the specific combination of Phong interpolation and the Phong reflection model.

Phong shading and the Phong reflection model were developed by Bui Tuong Phong at the University of Utah, who published them in his 1973 Ph.D. dissertation. Phong's methods were considered radical at the time of their introduction, but have evolved into a baseline shading method for many rendering applications.

Related Glossary Terms: Gouraud shading

Term Source: Chapter 14 – CGI and Effects in Films and Music Videos

Photon mapping

In computer graphics, photon mapping is a two-pass global illumination algorithm developed by Henrik Wann Jensen that approximately solves the rendering equation. Rays from the light source and rays from the camera are traced independently until some termination criterion is met, then they are connected in a second step to produce a radiance value. It is used to realistically simulate the interaction of light with different objects. Specifically, it is capable of simulating the refraction of light through a transparent substance such as glass or water, diffuse interreflection between illuminated objects, the subsurface scattering of light in translucent materials, and some of the effects caused by particulate matter such as smoke or water vapor. It can also be extended to more accurate simulations of light such as spectral rendering.

Related Glossary Terms:

Term Source: Chapter 19 – Global Illumination

Pixel

In digital imaging, a pixel, or pel, (picture element) is a physical point in a raster image, or the smallest, addressable element in a display device; so it is the smallest, controllable element of a picture represented on the screen. The address of a pixel corresponds to its physical coordinates. LCD pixels are manufactured in a two-dimensional grid, and are often represented using dots or squares, but CRT pixels correspond to their timing mechanisms and sweep rates.

Related Glossary Terms: Voxels

Term Source: Chapter 4 – MIT and Harvard

Plasma panel

A plasma display panel (PDP) is a type of flat panel display now commonly used for large TV displays (typically above 37-inch or 940 mm). Many tiny cells located between two panels of glass hold an inert mixture of noble gases. The gas in the cells is electrically turned into a plasma which then excites phosphors to emit light. Plasma displays are commonly confused with LCDs, another lightweight flatscreen display but with very different technology.

Related Glossary Terms: Cathode Ray Tube

Term Source: Chapter 3 – Other output devices

Post production

Post-production is part of filmmaking and the video production process. It occurs in the making of motion pictures, television programs, radio programs, advertising, audio recordings, photography, and digital art. It is a term for all stages of production occurring after the actual end of shooting and/or recording the completed work.

Post-production is, in fact, many different processes grouped under one name. These typically include:

- Video editing the picture of a television program using an edit decision list (EDL)
- Writing, (re)recording, and editing the soundtrack.
- Adding visual special effects – mainly computer-generated imagery (CGI) and digital copy from which release prints will be made (although this may be made obsolete by digital- cinema technologies).
- Sound design, Sound effects, ADR, Foley and Music, culminating in a process known as sound re-recording or mixing with professional audio equipment.
- Transfer of Color motion picture film to Video or DPX with a telecine and color grading (correction) in a color suite.

Related Glossary Terms:

Term Source: Chapter 6 – Cranston/Csuri Productions

Pre-visualizing

Pre-visualization (also known as pre-rendering, preview or wireframe windows) is a function to visualize complex scenes in movie before filming. It is also a concept in still photography. Pre-visualization is applied to techniques such as storyboarding, either in the form of charcoal drawn sketches or in digital technology in the planning

and conceptual of movie scenery make up. The advantage of pre-visualization is that it allows directors to experiment with different staging and art direction options – such as lighting, camera placement and movement, stage direction and editing – without having to incur the costs of actual production.

Related Glossary Terms:

Term Source: Chapter 8 – Wavefront Technologies

Procedural modeling

Procedural modeling is an umbrella term for a number of techniques in computer graphics to create 3D models and textures from sets of rules. L-Systems, fractals, and generative modeling are procedural modeling techniques since they apply algorithms for producing scenes. The set of rules may either be embedded into the algorithm, configurable by parameters, or the set of rules is separate from the evaluation engine. The output is called procedural content, which can be used in computer games, films, be uploaded to the internet, or the user may edit the content manually. Procedural models often exhibit database amplification, meaning that large scenes can be generated from a much smaller amount of rules. If the employed algorithm produces the same output every time, the output need not be stored. Often, it suffices to start the algorithm with the same random seed to achieve this.

Although all modeling techniques on a computer require algorithms to manage and store data at some point, procedural modeling focuses on creating a model from a rule set, rather than editing the model via user input. Procedural modeling is often applied when it would be too cumbersome to create a 3D model using generic 3D modelers, or when more specialized tools are required. This is often the case for plants, architecture or landscapes.

Related Glossary Terms:

Term Source: Chapter 8 – Side Effects

Procedural rendering

Procedural generation (procedural modeling, procedural rendering) is a widely used term in the production of media; it refers to content generated algorithmically (procedurally) rather than manually. Often, this means creating content on the fly rather than prior to distribution. This is often related to computer graphics applications and video game level design.

Related Glossary Terms:

Term Source: Chapter 6 – MAGI

Projective texture-mapping

Projective texture mapping is a method of texture mapping that allows a textured image to be projected onto a

scene as if by a slide projector. Projective texture mapping is useful in a variety of lighting techniques and it is the starting point for shadow mapping.

Related Glossary Terms: Texture Mapping

Term Source: Chapter 19 – Global Illumination

Prusinkiewicz, Przemyslaw

Przemyslaw (Przemek) Prusinkiewicz advanced the idea that Fibonacci numbers in nature can be in part understood as the expression of certain algebraic constraints on free groups, specifically as certain Lindenmayer grammars. Prusinkiewicz's main work is on the modeling of plant growth through such grammars.

Prusinkiewicz is currently a professor of Computer Science at the University of Calgary. Prusinkiewicz received the 1997 SIGGRAPH Computer Graphics Achievement Award for his work.

Related Glossary Terms:

Term Source: Chapter 19 – Plants

Q

Quantitative invisibility

In CAD/CAM, quantitative invisibility (QI) is the number of solid bodies that obscure a point in space as projected onto a plane. Often, CAD engineers project a model into a plane (a 2D drawing) in order to denote edges that are visible with a solid line, and those that are hidden with dashed or dimmed lines.

Related Glossary Terms: Hidden line elimination, Hidden surfaces

Term Source: Chapter 4 – Other research efforts

R

Radiosity

Radiosity (computer graphics), a rendering algorithm which gives a realistic rendering of shadows and diffuse light.

Radiosity is a global illumination algorithm used in 3D computer graphics rendering. Unlike direct illumination algorithms (such as Ray tracing), which tend to simulate light reflecting only once off each surface, global

illumination algorithms such as Radiosity simulate the many reflections of light around a scene, generally resulting in softer, more natural shadows and reflections.

Related Glossary Terms: Form factor

Term Source: Chapter 5 – Cornell and NYIT, Chapter 19 – Global Illumination

Random Access Memory

a type of computer memory that can be accessed randomly; that is, any byte of memory can be accessed without touching the preceding bytes. RAM is the most common type of memory found in computers and other devices, such as printers.

Related Glossary Terms:

Term Source: Chapter 15 – Early hardware

Range image

Range imaging is the name for a collection of techniques which are used to produce a 2D image showing the distance to points in a scene from a specific point, normally associated with some type of sensor device.

The resulting image, the range image, has pixel values which correspond to the distance, e.g., brighter values mean shorter distance, or vice versa. If the sensor which is used to produce the range image is properly calibrated, the pixel values can be given directly in physical units such as meters.

Related Glossary Terms:

Term Source: Chapter 20 – CG Icons

Raster-scanned

A raster scan, or raster scanning, is the rectangular pattern of image capture and reconstruction in television. By analogy, the term is used for raster graphics, the pattern of image storage and transmission used in most computer bitmap image systems. The word raster comes from the Latin word rastrum (a rake), which is derived from radere (to scrape)

Related Glossary Terms: Cathode Ray Tube, Vector

Term Source: Chapter 1 – Electronic devices

Ray casting

Ray casting is the use of ray-surface intersection tests to solve a variety of problems in computer graphics. The term was first used in computer graphics in a 1982 paper by Scott Roth to describe a method for rendering CSG models. The first ray casting (versus ray tracing) algorithm used for rendering was presented by Arthur Appel in 1968. The idea behind ray casting is to shoot rays from the eye, one per pixel, and find the closest object blocking the path of that ray – think of an image as a screen-door, with each square in the screen being a pixel. This is then the object the eye normally sees through that pixel. Using the material properties and the effect of the lights in the scene, this algorithm can determine the shading of this object. The simplifying assumption is made that if a surface faces a light, the light will reach that surface and not be blocked or in shadow. The shading of the surface is computed using traditional 3D computer graphics shading models. One important advantage ray casting offered over older scan-line algorithms is its ability to easily deal with non-planar surfaces and solids, such as cones and spheres. If a mathematical surface can be intersected by a ray, it can be rendered using ray casting. Elaborate objects can be created by using solid modeling techniques and easily rendered.

Ray casting for producing computer graphics was first used by scientists at Mathematical Applications Group, Inc., (MAGI) of Elmsford, New York.

Roth, Scott D. (February 1982), “Ray Casting for Modeling Solids”, Computer Graphics and Image Processing 18 (2): 109–144

Goldstein, R. A., and R. Nagel. 3-D visual simulation. Simulation 16(1), pp. 25–31, 1971.

Related Glossary Terms: Ray-trace, Scanline rendering

Term Source: Chapter 11 – R/Greenberg Associates / Blue Sky Studios

Ray-trace

Optical ray tracing describes a method for producing visual images constructed in 3D computer graphics environments, with more photorealism than either ray casting or scanline rendering techniques. It works by tracing a path from an imaginary eye through each pixel in a virtual screen, and calculating the color of the object visible through it.

Ray tracing is capable of simulating a wide variety of optical effects, such as reflection and refraction, scattering, and dispersion phenomena (such as chromatic aberration).

Related Glossary Terms: Radiosity, Reflection mapping, Rendering, Scanline rendering

Term Source: Chapter 5 – Cal Tech and North Carolina State

Reeves, Bill

William “Bill” Reeves is the technical director who worked with John Lasseter on the animation breakthrough

shorts Luxo Jr and The Adventures of André and Wally B. at ILM and Pixar. After obtaining a Ph.D. at the University of Toronto, Reeves was hired by George Lucas as a member of Industrial Light and Magic. He was one of the founding employees of Pixar when it was sold in 1986 to Steve Jobs. Reeves is the inventor of the first Motion Blur algorithm and methods to simulate particle motion in CGI. Reeves received the Academy Award for Best Animated Short Film (Oscar) in 1988 for his work (with John Lasseter) on the film Tin Toy. Their collaboration continued with Reeves acting as the Supervising Technical Director of the first feature length, computer-animated film Toy Story.

Related Glossary Terms:

Term Source: Chapter 19 – Particle Systems and Artificial Life

Reflection mapping

In computer graphics, environment mapping, or reflection mapping, is an efficient image- based lighting technique for approximating the appearance of a reflective surface by means of a precomputed texture image. The texture is used to store the image of the distant environment surrounding the rendered object.

Several ways of storing the surrounding environment are employed. The first technique was sphere mapping, in which a single texture contains the image of the surroundings as reflected on a mirror ball. It has been almost entirely surpassed by cube mapping, in which the environment is projected onto the six faces of a cube and stored as six square textures or unfolded into six square regions of a single texture.

Related Glossary Terms: Environment mapping, Radiosity

Term Source: Chapter 5 – Cornell and NYIT

Refraction

Refraction is the phenomenon when a wave changes direction due to a change in speed of the wave, most notably in response to the wave traveling from one medium to another. This is most commonly discussed in reference to the change in the path of a light beam, but affects other waves such as sound as well.

The rule which describes this change in direction is known as Snell’s Law, which says that the proportion of the sines of the angles are equal to the inverse proportion of the indices of refraction and also to the proportion of the velocities.

Related Glossary Terms:

Term Source: Chapter 20 – CG Icons

Remote sensing

Remote sensing is the acquisition of information about an object or phenomenon, without making physical contact with the object. In modern usage, the term generally refers to the use of aerial sensor technologies to detect and classify objects on Earth (both on the surface, and in the atmosphere and oceans) by means of propagated signals (e.g. electromagnetic radiation emitted from aircraft or satellites)

Related Glossary Terms:

Term Source: Chapter 18 – Algorithms

Render farm

A render farm is high performance computer system, e.g. a computer cluster, built to render computer-generated imagery (CGI), typically for film and television visual effects.

The rendering of images is a highly parallelizable activity, as each frame usually can be calculated independently of the others, with the main communication between processors being the upload of the initial source material, such as models and textures, and the download of the finished images.

Related Glossary Terms:

Term Source:

Chapter 11 – Rhythm and Hues / Xaos

Rendering

Rendering is the process of generating an image from a model (or models in what collectively could be called a scene file), by means of computer programs.

Related Glossary Terms:

Term Source: Chapter 4 – University of Utah, Chapter 4 – The Ohio State University

Rendering equation

The rendering equation is an integral equation in which the equilibrium radiance leaving a point is given as the sum of emitted plus reflected radiance under a geometric optics approximation. It was simultaneously introduced into computer graphics by David Immel et al. and James Kajiya in 1986. The various realistic rendering techniques in computer graphics attempt to solve this equation.

The physical basis for the rendering equation is the law of conservation of energy. Assuming that L denotes radiance, we have that at each particular position and direction, the outgoing light (Lo) is the sum of the emitted

light (Le) and the reflected light. The reflected light itself is the sum of the incoming light (Li) from all directions, multiplied by the surface reflection and cosine of the incident angle.

Related Glossary Terms:

Term Source: Chapter 19 – Global Illumination

Reynolds, Craig

Craig W. Reynolds (born March 15, 1953), is an artificial life and computer graphics expert, who created the Boids artificial life simulation in 1986. Reynolds worked on the film Tron (1982) as a scene programmer, and on Batman Returns (1992) as part of the video image crew. Reynolds won the 1998 Academy Scientific and Technical Award in recognition of "his pioneering contributions to the development of three-dimensional computer animation for motion picture production." He is the author of the OpenSteer library.

Related Glossary Terms:

Term Source: Chapter 6 – Information International Inc. (Triple-I)

Rig removal (wire removal)

A post production technique that is used to remove elements of an image or sequence that were needed during the principle photography, but must be taken out for the finished shot.

For example, a production technique called a "wire gag" is used where the talent is fitted with wires to either assist him to jump, fall or otherwise move in a non-normal way, or as a safety feature to save him from injury or death.

Wires are often also used for explosions. An explosion that would blow the extras into the air is not possible, so wire harnesses are added to the on-screen talent and they are yanked away from the explosion as or before it takes place.

Another example similar to wire removal is rig removal. A rig is any kind of device used on the set to hold up an item up for filming, or items in a scene that can't be eliminated before the shot. After shooting, it must then be removed from the scene.

The post process requires replacing the scene including the rig or wire with a clean view. It can be a clean background frame for the area covered by the offending item (clean plate) and may also require a matte painting if a clean plate can't be provided.

Related Glossary Terms:

Term Source: Chapter 6 – Pacific Data Images (PDI)

RISC

Reduced instruction set computing, or RISC, is a CPU design strategy based on the insight that simplified (as opposed to complex) instructions can provide higher performance if this simplicity enables much faster execution of each instruction. A computer based on this strategy is a reduced instruction set computer also called RISC.

Related Glossary Terms:

Term Source: Chapter 15 – Apollo / Sun / SGI

Roberts, Lawrence

Lawrence G. Roberts designed and managed the first packet network, the ARPANET (the precursor to the Internet). At that time, in 1967, Dr. Roberts became the Chief Scientist of ARPA taking on the task of designing, funding, and managing the radically new communications network concept of packet switching. Since then Dr. Roberts has founded five startups; Telenet, NetExpress, ATM Systems, Caspian Networks, and Anagran.

Roberts wrote the first algorithm to eliminate hidden or obscured surfaces from a perspective picture. In 1965, Roberts implemented a homogeneous coordinate scheme for transformations and perspective. His solutions to these problems prompted attempts to find faster algorithms for generating hidden surfaces.

Related Glossary Terms:

Term Source: Chapter 4 – MIT and Harvard

Rosebush, Judson

Judson Rosebush is a director and producer of multimedia products and computer animation, an author, artist and media theorist. He is the founder of Digital Effects Inc. and the Judson Rosebush Company. He is the former editor of Pixel Vision magazine, the serialized Pixel Handbook, and a columnist for CD-ROM Professional magazine. He has worked in radio and TV, film and video, sound, print, and hypermedia, including CD-ROM and the Internet. He has been an ACM National Lecturer since the late 1980s and is a recipient of its Distinguished Speaker Award.

Related Glossary Terms:

Term Source: Chapter 6 – Digital Effects

Rosendahl, Carl

Carl graduated with a BSEE from Stanford University in 1979 and founded Pacific Data Images in 1980. PDI became, and continues to be, one of the pioneering and most highly innovative creators of computer animation for

film and television. During his 20 years of leading the organization, PDI produced over 700 commercials, worked on visual effects for over 70 feature films and, in partnership with DreamWorks SKG, produced the hit animated film “Antz” and the Academy Award winning “Shrek.” Carl received multiple Emmy Awards and in 1998 was recognized with a Technical Achievement Academy Award for PDI’s contributions to modern filmmaking. In early 2000 he sold PDI to DreamWorks SKG, where the company continues to develop and produce animated feature films, including the “Shrek” series and “Madagascar.”

Carl is currently a faculty member of Carnegie Mellon’s Entertainment Technology Center. Prior to joining Carnegie Mellon, Carl was the CEO and founder of Uth TV, a television and web outlet tapping into the exploding power of youth voice and digital storytelling.

From 2000 through 2002, Carl was a Managing Director at Mobius Venture Capital (formerly Softbank Venture Capital) where he focused on investments in the technology and media space.

Carl is also active with a number of non-profit organizations and was a founding board member of the Visual Effects Society (VES) in 1995 and served as the Chair of the Society’s Board of Directors from 2004 through 2006.

Related Glossary Terms:

Term Source: Chapter 6 – Pacific Data Images (PDI)

Rotoscoping

to rotoscope is to create an animated matte indicating the shape of an object or actor at each frame of a sequence, as would be used to composite a CGI element into the background of a live-action shot. 2. Historically, a rotoscope was a kind of projector used to create frame-by-frame alignment between filmed live-action footage and hand-drawn animation. Mounted at the top of an animation stand, a rotoscope projected filmed images down through the actual lens of the animation camera and onto the page where animators draw and compose images.

Related Glossary Terms: Motion capture

Term Source: Chapter 6 – Bo Gehring and Associates

Run length encoding

Run-length encoding (RLE) is a very simple form of data compression in which runs of data (that is, sequences in which the same data value occurs in many consecutive data elements) are stored as a single data value and count, rather than as the original run. This is most useful on data that contains many such runs: for example, simple graphic images such as icons, line drawings, and animations. It is not useful with files that don’t have many runs as it could greatly increase the file size.

RLE may also be used to refer to an early graphics file format supported by CompuServe for compressing black and white images, but was widely supplanted by their later Graphics Interchange Format

Related Glossary Terms: Raster-scanned

Term Source: Chapter 4 – University of Utah, Chapter 4 – The Ohio State University

S

SAGE

The Semi-Automatic Ground Environment (SAGE) was the Cold War operator environment created for the automated air defense (AD) of North American and by extension, the name of the associated network of radars, computer systems, and aircraft command and control equipment (“SAGE Defense System”)

Related Glossary Terms:

Term Source:

Chapter 2 – Whirlwind and SAGE

Sandin, Dan

Daniel J. Sandin (born 1942) is a video and computer graphics artist/researcher. He is a Professor Emeritus of the School of Art & Design, University of Illinois at Chicago, and Co- director of the Electronic Visualization Laboratory at the University of Illinois at Chicago. He is an internationally recognized pioneer in computer graphics, electronic art and visualization.

Related Glossary Terms: MOOG synthesizer

Term Source: Chapter 5 – Illinois-Chicago and University of Pennsylvania

Scanline rendering

Scanline rendering is an algorithm for visible surface determination, in 3D computer graphics, that works on a row-by-row basis rather than a polygon-by-polygon or pixel-by- pixel basis. All of the polygons to be rendered are first sorted by the top y coordinate at which they first appear, then each row or scan line of the image is computed using the intersection of a scan line with the polygons on the front of the sorted list, while the sorted list is updated to discard no-longer-visible polygons as the active scan line is advanced down the picture.

Related Glossary Terms:

Term Source:

Schure, Alexander

Alexander Schure founded the New York Institute of Technology (NYIT) in 1955. He also served as the Chancellor of Nova Southeastern University (NSU) from 1970 until 1985.

Schure was an early and decisive champion of computer animation. For almost five years, NYIT gave research funding and a home to the brain trust that would evolve into Pixar Animation Studios. In November, 1974, Schure hired recent University of Utah doctoral graduate Edwin Catmull to direct NYIT's fledgling computer graphics lab. The core technical team included computer animation pioneers Catmull, Alvy Ray Smith, David DiFrancesco, Ralph Guggenheim, Jim Blinn, and Jim Clark.

Related Glossary Terms:

Term Source: Chapter 5 – Cornell and NYIT

Schwartz, Lillian

Lillian F. Schwartz is an American artist who is known for being a creator of 20th century computer-developed art. One notable work she created is Mona Leo, where she morphed the image of a Leonardo da Vinci self-portrait with the Mona Lisa. She made one of the first digitally created films to be shown as a work of art, Pixillation, which shows diagonal red squares and other shapes such as cones and pyramids on black on white backgrounds. She worked in the early stages of her career with Bell Laboratories, developing mixtures of sound, video, and art. Afterwards, during the 1980s, Schwartz experimented with manipulating artwork images using computer technology and creating artwork of her own.

Related Glossary Terms:

Term Source: Chapter 9 – Lillian Schwartz

Scientific visualization

Scientific visualization (also spelled scientific visualisation) is an interdisciplinary branch of science according to Friendly "primarily concerned with the visualization of three- dimensional phenomena (architectural, meteorological, medical, biological, etc.), where the emphasis is on realistic renderings of volumes, surfaces, illumination sources, and so forth, perhaps with a dynamic (time) component". It is also considered a branch of computer science that is a subset of computer graphics. The purpose of scientific visualization is to graphically illustrate scientific data to enable scientists to understand, illustrate, and glean insight from their data.

Michael Friendly (2008). "Milestones in the history of thematic cartography, statistical graphics, and data visualization"

Related Glossary Terms: Modular visualization environments, Visualization, Volume visualization

Term Source: Chapter 18 – Introduction

Sims, Karl

Karl Sims is a computer graphics artist and researcher, who is best known for using particle systems and artificial life in computer animation. Sims received a B.S. from MIT in 1984, and a M.S. from the MIT Media Lab in 1987. He worked for Thinking Machines as an artist- in-residence, for Whitney-Demos Production as a researcher, and co-founded Optomystic. He currently heads GenArts, a Cambridge, Massachusetts company that develops special effects plugins used by motion picture studios.

Related Glossary Terms:

Term Source: Chapter 19 – Particle Systems and Artificial Life

Sketchpad

Sketchpad was a revolutionary computer program written by Ivan Sutherland in 1963 in the course of his PhD thesis, for which he received the Turing Award in 1988. It helped change the way people interact with computers. Sketchpad is considered to be the ancestor of modern computer-aided drafting (CAD) programs as well as a major breakthrough in the development of computer graphics in general. For example, the Graphic User Interface was derived from the Sketchpad as well as modern object oriented programming.

Related Glossary Terms:

Term Source: Chapter 3 – Work continues at MIT

Slit-scan

Originally used in static photography to achieve blurriness or deformity, the slit-scan technique was perfected for the creation of spectacular animations. It enables the cinematographer to create a psychedelic flow of colors. It was adapted for film by Douglas Trumbull during the production of Stanley Kubrick’s 2001: A Space Odyssey and used extensively in the “stargate” sequence.

This type of effect was revived in other productions, for films and television alike. For instance, slit-scan was used by Bernard Lodge to create the Doctor Who title sequences for Jon Pertwee and Tom Baker used between December 1973 and January 1980. Slit-scan was also used in Star Trek: The Next Generation to create the “stretching” of the starship Enterprise-D when it engaged warp drive. Due to the expense and difficulty of this technique, the same three warp-entry shots, all created by Industrial Light and Magic for the series pilot, were reused throughout the series virtually every time the ship went into warp.

Related Glossary Terms:

Term Source: Chapter 6 – Robert Abel and Associates

Solids modeling

Solid modeling (or modeling) is a consistent set of principles for mathematical and computer modeling of three-dimensional solids. Solid modeling is distinguished from related areas of geometric modeling and computer graphics by its emphasis on physical fidelity. Together, the principles of geometric and solid modeling form the foundation of computer-aided design and in general support the creation, exchange, visualization, animation, interrogation, and annotation of digital models of physical objects.

Related Glossary Terms: B-rep, CSG

Term Source: Chapter 6 – MAGI

Spacewar

Spacewar! is one of the earliest known digital computer games. It is a two-player game, with each player taking control of a spaceship and attempting to destroy the other. A star in the centre of the screen pulls on both ships and requires maneuvering to avoid falling into it. In an emergency, a player can enter hyperspace to return at a random location on the screen, but only at the risk of exploding if it is used too often.

Steve “Slug” Russell, Martin “Shag” Graetz, and Wayne Wiitanen of the fictitious “Hingham Institute” conceived of the game in 1961, with the intent of implementing it on a DEC PDP-1 at the Massachusetts Institute of Technology.

Related Glossary Terms:

Term Source: Chapter 3 – TX-2 and DEC

Specular reflection

Specular reflection is the mirror-like reflection of light (or of other kinds of wave) from a surface, in which light from a single incoming direction (a ray) is reflected into a single outgoing direction. Such behavior is described by the law of reflection, which states that the direction of incoming light (the incident ray), and the direction of outgoing light reflected (the reflected ray) make the same angle with respect to the surface normal, thus the angle of incidence equals the angle of reflection.

Related Glossary Terms: Diffuse reflection, Lambertian

Term Source:

Splatting

In direct volume rendering, Splatting is a technique which trades quality for speed. Here, every volume element is splatted, as Lee Westover said, like a snow ball, on to the viewing surface in back to front order. These splats are rendered as disks whose properties (color and transparency) vary diametrically in normal (Gaussian) manner. Flat disks and those with other kinds of property distribution are also used depending on the application.

Related Glossary Terms: Volume Rendering

Term Source: Chapter 18 – Volumes

Sprite

In computer graphics, a sprite is a two-dimensional image or animation that is integrated into a larger scene. Initially used to describe graphical objects handled separately from the memory bitmap of a video display, the term has since been applied more loosely to refer to various elements of graphical overlays.

Originally, sprites were a method of integrating unrelated bitmaps so that they appeared to be part of the normal bitmap on a screen, such as creating an animated character that can be moved on a screen without altering the data defining the overall screen. Such sprites can be created by either electronic circuitry or software. In circuitry, a hardware sprite is a hardware construct that employs custom DMA channels to integrate visual elements with the main screen in that it super-imposes two discrete video sources. Software can simulate this through specialized rendering methods.

As three-dimensional graphics became more prevalent, the term was used to describe a technique whereby flat images are seamlessly integrated into complicated three- dimensional scenes, often as textures on 2D or 3D objects whose normal always faced the camera.

Related Glossary Terms:

Term Source: Chapter 15 – Influence of Games

Stereoscopic display

Stereoscopy (also called stereoscopics or 3-D imaging) refers to a technique for creating or enhancing the illusion of depth in an image by presenting two offset images separately to the left and right eye of the viewer. These two-dimensional images are then combined in the brain to give the perception of 3-D depth. Besides the technique of free viewing, which must be learned by the viewer, three strategies have been used to mechanically present different images to each eye: have the viewer wear eyeglasses to combine separate images from two offset sources, have the viewer wear eyeglasses to filter offset images from a single source separated to each eye, or have the light source split the images directionally into the viewer’s eyes (no glasses required; known as Autostereoscopy)

Related Glossary Terms: Head-mounted displays

Term Source: Chapter 17 – Virtual Reality

Stop-Motion

Stop motion (also known as stop frame) is an animation technique to make a physically manipulated object appear to move on its own. The object is moved in small increments between individually photographed frames, creating the illusion of movement when the series of frames is played as a continuous sequence. Dolls with movable joints or clay figures are often used in stop motion for their ease of repositioning. Stop motion animation using clay is called clay animation or “clay mation”

Related Glossary Terms:

Term Source: Chapter 14 – CGI and Effects in Films and Music Videos

Storage tube

An electron tube in which information is stored as charges for a predetermined time

Related Glossary Terms: Cathode Ray Tube, Vacuum tube

Term Source: Chapter 1 – Electronic devices

Storage tube vector graphics

a storage tube is a special monochromatic CRT whose screen has a kind of ‘memory’ (hence the name): when a portion of the screen is illuminated by the CRT’s electron gun, it stays lit until a screen erase command is given. Thus, screen update commands need only be sent once and this allows the use of a slower data connection, typically serial—a feature very well adapted to computer terminal use in 1960s and 1970s computing. The two main advantages were:

▪ Very low bandwidth needs compared to vector graphics displays, thus allowing much longer cable distances between computer and terminal

▪ No need for display-local RAM (as in modern terminals), which was prohibitively expensive at the time.

Related Glossary Terms:

Term Source: Chapter 3 – Other output devices

Supercomputing

A powerful computer that can process large quantities of data of a similar type very quickly

Related Glossary Terms:

Term Source: Chapter 4 – Bell Labs and Lawrence Livermore

Surface of revolution

A surface of revolution is a surface in Euclidean space created by rotating a curve (the generatrix) around a straight line in its plane (the axis).

Related Glossary Terms:

Term Source: Chapter 20 – CG Icons

Sutherland, Ivan

Ivan Edward Sutherland (born May 16, 1938)[1] is an American computer scientist and Internet pioneer. He received the Turing Award from the Association for Computing Machinery in 1988 for the invention of Sketchpad, an early predecessor to the sort of graphical user interface that has become ubiquitous in personal computers. He was a professor at Utah when he co-founded computer graphics company Evans and Sutherland (E&S) in 1968.

Related Glossary Terms:

Term Source: Chapter 3 – Work continues at MIT

Synthespians

A virtual human or digital clone is the creation or re-creation of a human being in image and voice using computer-generated imagery and sound. The process of creating such a virtual human on film, substituting for an existing actor, is known, after a 1992 book, as Schwarzeneggerization, and in general virtual humans employed in movies are known as synthespians, virtual actors, vactors, cyberstars, or “silicentric” actors.

Related Glossary Terms:

Term Source: Chapter 11 – Kleiser Walczak Construction Company

T

Taylor, Richard

Richard Taylor is a director, production designer and special effects supervisor. He was the Visual Effects Supervisor for the movie, TRON and was responsible for organizing the effects and designing the film's graphics and costumes, as well as blending the live-action footage with the CGI animation.

He began his career as an artist and holds a BFA in painting & drawing from the University of Utah. After graduation he co-founded Rainbow Jam, a multi-media light show and graphics company which gave concert performances in tandem with top musical groups such as The Grateful Dead, Santana, Led Zeppelin and Jethro Tull. In 1971 he received the Cole Porter Fellowship from USC where he earned an MFA in Print Making and Photography. In 1973, Richard joined Robert Abel and Associates. He directed many award-winning television commercials and received four Clio awards for his work on the 7UP Bubbles "See the Light", 7UP "Uncola" and the Levi's "Trademark" commercials. During his tenure at the Abel Studio he created many of the on air graphics for ABC television and designed new theatrical logos for CBS Theatrical Films and Columbia Pictures.

He supervised the design and construction of the miniatures and designed and directed special effects sequences for Paramount's' STAR TREK, THE MOTION PICTURE. In 1978, he became the creative director at Information International Inc. (III). While at III Richard directed many of the first computer generated commercials and designed and directed the special effects for the feature film "LOOKER" which was written and directed by Michael Crichton.

In 1981 Richard became the Special Effects Director of Walt Disney's TRON, the innovative film that introduced America to the world of computer simulation. Following TRON, Richard opened the West Coast office of Magi Synthavision, the computer animation studio that along with III generated the computer simulation scenes for Tron. One of the first commercials Richard directed at Magi, "Worm War One" won the first Clio for Computer Animation.

He was also at Apogee Production Inc. Lee Lacy & Associates, Image Point Productions, Dryer/Taylor Productions, and Rhythm & Hues Studios.

Related Glossary Terms:

Term Source: Chapter 6 – MAGI

Terzopoulos, Demetri

Demetri Terzopoulos is a professor at the University of California, Los Angeles, where he directs the UCLA Computer Graphics and Vision Laboratory. After graduation from MIT, he was a research scientist at the MIT Artificial Intelligence Lab, then joined the University of Toronto His published work is in computer vision, computer graphics, medical image analysis, computer-aided design, and artificial intelligence/life. Professor Terzopoulos is the recipient of a 2005 Academy Award for Technical Achievement from the Academy of Motion Picture Arts and Sciences for his pioneering work on realistic cloth simulation for motion pictures. In 2007, he was

the inaugural recipient of the Computer Vision Significant Researcher Award from the IEEE “For his pioneering and sustained research on Deformable Models and their applications”.

Related Glossary Terms:

Term Source: Chapter 19 – Physical-based Modeling

Tesler, Larry

Larry Tesler is a computer scientist working in the field of human-computer interaction. Tesler studied computer science at Stanford and worked for a time at the Stanford Artificial Intelligence Laboratory. From 1973 to 1980, he was at Xerox PARC, where, among other things, he worked on the Gypsy word processor and Smalltalk. Copy and paste was first implemented in 1973-1976 by Tesler while working on the programming of Smalltalk-76 at Xerox Palo Alto Research Center.

In 1980, Tesler moved to Apple Computer, where he held various positions, including Vice President of AppleNet, Vice President of the Advanced Technology Group, and Chief Scientist. He worked on the Lisa team, and was enthusiastic about the development of the Macintosh as the successor to the Lisa. In 1985, Tesler worked with Niklaus Wirth to add object-oriented language extensions to the Pascal programming language, calling the new language Object Pascal. He also was instrumental in developing MacApp, one of the first class libraries for application development. Eventually, these two technologies became shipping Apple products. Starting in 1990, Tesler led the efforts to develop the Apple Newton, initially as Vice President of the Advanced Development Group, and then as Vice President of the Personal Interactive Electronics division.

Related Glossary Terms:

Term Source: Chapter 16 – Xerox PARC

Texture Mapping

Texture mapping is a method for adding detail, surface texture (a bitmap or raster image), or color to a computer-generated graphic or 3D model. Its application to 3D graphics was pioneered by Dr Edwin Catmull in his Ph.D. thesis of 1974

Related Glossary Terms: Multi-texturing

Term Source:

Transistor

A semiconductor device that amplifies, oscillates, or switches the flow of current between two terminals by

varying the current or voltage between one of the terminals and a third: although much smaller in size than a vacuum tube, it performs similar functions without requiring current to heat a cathode.

Related Glossary Terms: Vacuum tube

Term Source: Chapter 1 – Electronic devices

Troubetskoy, Eugene

Dr. Eugene Troubetzkoy had a PhD in Theoretical Physics from Columbia and worked as a nuclear physicist to create computer simulations of nuclear particle behavior. He is credited with helping develop the amazing technique for capturing 3D scenes with remarkable realism called Raytrace rendering. He was one of the founders of Blue Sky.

Related Glossary Terms:

Term Source: Chapter 6 – MAGI

Turnkey

a computer system purchased from hardware and software vendors, customized and put in working order by a firm that then sells the completed system to the client that ordered it.

Related Glossary Terms:

Term Source:

Chapter 10 – Auto-trol / Applicon / ComputerVision

Tweening

Short for in-betweening, the process of generating intermediate frames between two images to give the appearance that the first image evolves smoothly into the second image. Tweening is a key process in all types of animation, including computer animation. Sophisticated animation software enables you to identify specific objects in an image and define how they should move and change during the tweening process.

Related Glossary Terms: Keyframe

Term Source: Chapter 8 – Introduction

U/V

Vacuum tube

1. Also called, especially British , vacuum valve . an electron tube from which almost all air or gas has been evacuated: formerly used extensively in radio and electronics.

2. A sealed glass tube with electrodes and a partial vacuum or a highly rarefied gas, used to observe the effects of a discharge of electricity passed through it.

The vacuum tube was invented by Lee de Forest in 1906. It was an improvement on the Fleming tube, or Fleming valve, introduced by John Ambrose Fleming two years earlier. The vacuum tube contains three components: the anode, the cathode and a control grid. It could therefore control the flow of electrons between the anode and cathode using the grid, and could therefore act as a switch or an amplifier.

Related Glossary Terms: Cathode Ray Tube, Transistor

Term Source: Chapter 1 – Electronic devices

Van Dam, Andy

Andries “Andy” van Dam (born 8 December 1938, Groningen) is a Dutch-born American professor of computer science and former Vice-President for Research at Brown University in Providence, Rhode Island. Together with Ted Nelson he contributed to the first hypertext system, HES in the late 1960s. He co-authored Computer Graphics: Principles and Practice along with J.D. Foley, S.K. Feiner, and John Hughes. He also co-founded the precursor of today’s ACM SIGGRAPH conference.

Related Glossary Terms:

Term Source: Chapter 5 – Other labs and NSF

Vector Graphics

Vector graphics is the use of geometrical primitives such as points, lines, curves, and shapes or polygon(s), which are all based on mathematical expressions, to represent images in computer graphics. “Vector”, in this context, implies more than a straight line.

Vector graphics is based on images made up of vectors (also called paths, or strokes) which lead through locations called control points. Each of these points has a definite position on the x and y axes of the work plan. Each point, as well, is a variety of database, including the location of the point in the work space and the direction of the vector (which is what defines the direction of the track). Each track can be assigned a color, a shape, a thickness and also a fill. This does not affect the size of the files in a substantial way because all information resides in the structure; it describes how to draw the vector.

Related Glossary Terms: Cathode Ray Tube, Raster-scanned

Term Source: Chapter 1 – Electronic devices

Videosynthesizer

A Video Synthesizer is a device that electronically creates a video signal. A video synthesizer is able to generate a variety of visual material without camera input through the use of internal video pattern generators, as seen in the still frames of motion sequences shown above. It can also accept and "clean up and enhance" or "distort" live television camera imagery. The synthesizer creates a wide range of imagery through purely electronic manipulations. This imagery is visible within the output video signal when this signal is displayed. The output video signal can be viewed on a wide range of conventional video equipment, such as TV monitors, theater video projectors, computer displays, etc.

Related Glossary Terms:

Term Source: Chapter 12 – Image West / Dolphin Productions / Ron Hays

Virtual memory

In computing, virtual memory is a memory management technique developed for multitasking kernels. This technique virtualizes a computer architecture's various forms of computer data storage (such as random-access memory and disk storage), allowing a program to be designed as though there is only one kind of memory, "virtual" memory, which behaves like directly addressable read/write memory (RAM).

Related Glossary Terms:

Term Source: Chapter 3 – TX-2 and DEC

Virtual reality

Virtual reality (VR), is a term that applies to computer-simulated environments that can simulate physical presence in places in the real world, as well as in imaginary worlds. Most current virtual reality environments are primarily visual experiences, displayed either on a computer screen or through special stereoscopic displays, but some simulations include additional sensory information, such as sound through speakers or headphones. Some advanced, haptic systems now include tactile information, generally known as force feedback, in medical and gaming applications. Furthermore, virtual reality covers remote communication environments which provide virtual presence of users with the concepts of telepresence and telexistence or a virtual artifact (VA) either through the use of standard input devices such as a keyboard and mouse, or through multimodal devices such as a wired glove, devices such as the Polhemus, and omnidirectional treadmills.

Related Glossary Terms: Augmented reality

Term Source: Chapter 17 – Virtual Reality

Vistavision

VistaVision is a higher resolution, widescreen variant of the 35mm motion picture film format which was created by engineers at Paramount Pictures in 1954.

Paramount did not use anamorphic processes such as CinemaScope but refined the quality of their flat widescreen system by orienting the 35mm negative horizontally in the camera gate and shooting onto a larger area, which yielded a finer-grained projection print.

Related Glossary Terms:

Term Source: Chapter 11 – Kleiser Walczak Construction Company

Visualization

Visualization is any technique for creating images, diagrams, or animations to communicate a message. Visualization through visual imagery has been an effective way to communicate both abstract and concrete ideas since the dawn of man. Examples from history include cave paintings, Egyptian hieroglyphs, Greek geometry, and Leonardo da Vinci's revolutionary methods of technical drawing for engineering and scientific purposes.

Visualization today has ever-expanding applications in science, education, engineering (e.g., product visualization), interactive multimedia, medicine, etc. Typical of a visualization application is the field of computer graphics. The invention of computer graphics may be the most important development in visualization since the invention of central perspective in the Renaissance period. The development of animation also helped advance visualization.

Related Glossary Terms: Scientific visualization

Term Source: Chapter 18 – Introduction

VLSI

Very-large-scale integration (VLSI) is the process of creating integrated circuits by combining thousands of transistors into a single chip. VLSI began in the 1970s when complex semiconductor and communication technologies were being developed. The microprocessor is a VLSI device.

Related Glossary Terms:

Term Source: Chapter 15 – Apollo / Sun / SGI

Volume Rendering

In scientific visualization and computer graphics, volume rendering is a set of techniques used to display a 2D projection of a 3D discretely sampled data set.

A typical 3D data set is a group of 2D slice images acquired by a CT, MRI, or MicroCT scanner. Usually these are acquired in a regular pattern (e.g., one slice every millimeter) and usually have a regular number of image pixels in a regular pattern. This is an example of a regular volumetric grid, with each volume element, or voxel represented by a single value that is obtained by sampling the immediate area surrounding the voxel.

Related Glossary Terms: Volume visualization

Term Source: Chapter 18 – Volumes

Volume visualization

Volume visualization (Kaufman, 1992) – a direct technique for visualizing volume primitives without any intermediate conversion of the volumetric data set to surface representation.

Related Glossary Terms: Volume Rendering

Term Source: Chapter 18 – Introduction

Voxels

A voxel (volumetric pixel or Volumetric Picture Element) is a volume element, representing a value on a regular grid in three dimensional space. This is analogous to a pixel, which represents 2D image data in a bitmap (which is sometimes referred to as a pixmap). As with pixels in a bitmap, voxels themselves do not typically have their position (their coordinates) explicitly encoded along with their values. Instead, the position of a voxel is inferred based upon its position relative to other voxels (i.e., its position in the data structure that makes up a single volumetric image). In contrast to pixels and voxels, points and polygons are often explicitly represented by the coordinates of their vertices. A direct consequence of this difference is that polygons are able to efficiently represent simple 3D structures with lots of empty or homogeneously filled space, while voxels are good at representing regularly sampled spaces that are non-homogeneously filled.

Related Glossary Terms: Pixel

Term Source: Chapter 18 – Volumes

W

Walker, John

John Walker is a computer programmer and a co-founder of the computer-aided design software company Autodesk, and a co-author of early versions of AutoCAD, a product Autodesk originally acquired from programmer Michael Riddle.

Related Glossary Terms:

Term Source: Chapter 8 – Autodesk/Kinetix/Discreet

Warnock, John

John Warnock is best known as the co-founder with Charles Geschke of Adobe Systems Inc., the graphics and publishing software company. Warnock has pioneered the development of graphics, publishing, Web and electronic document technologies that have revolutionized the field of publishing and visual communications. He was part of the pioneering work at the University of Utah while a graduate student there.

In 1976, while Warnock worked at Evans & Sutherland, the computer graphics company, the concepts of the PostScript language were seeded. Prior to co-founding Adobe, Warnock worked at Xerox's Palo Alto Research Center (Xerox PARC). Unable to convince Xerox management of the approach to commercialize the InterPress graphics language for controlling printing, he left Xerox to start Adobe in 1982. At their new company, they developed an equivalent technology, PostScript, from scratch, and brought it to market for Apple's LaserWriter in 1984.

In his 1969 doctoral thesis, Warnock invented the Warnock algorithm for hidden surface determination in computer graphics. It works by recursive subdivision of a scene until areas are obtained that are trivial to compute. It solves the problem of rendering a complicated image by avoiding the problem. If the scene is simple enough to compute then it is rendered; otherwise it is divided into smaller parts and the process is repeated.

In the Spring of 1991, Warnock outlined a system called "Camelot" that evolved into the Portable Document Format (PDF) file-format. The goal of Camelot was to "effectively capture documents from any application, send electronic versions of these documents anywhere, and view and print these documents on any machines".

One of Adobe's popular typefaces, Warnock, is named after him.

Related Glossary Terms:

Term Source: Chapter 16 – Xerox PARC

Wedge, Chris

Chris Wedge received his BFA in Film from State University of New York at Purchase in Purchase, New York in

1981, and subsequently earned his MA in computer graphics and art education at the Ohio State University. He has taught animation at the School of Visual Arts in New York City where he met his future film directing partner, Carlos Saldanha. Wedge is co-founder and Vice President of Creative Development at Blue Sky Studios and is the owner of WedgeWorks, a film production company founded by Wedge.

In 1982, Wedge worked for MAGI/SynthaVision, where he was a principal animator on the Disney film Tron, credited as a scene programmer. Some of his other works include Where the Wild Things Are (1983), Dinosaur Bob, George Shrinks, and Santa Calls. In 1998, he won an Academy Award for the short animated film, Bunny. He is also the voice of Scrat in the Ice Age film series, performing the character's "squeaks and squeals".[2]

Related Glossary Terms:

Term Source: Chapter 6 – MAGI

Wein, Marceli

NRC scientists Nestor Burtnyk and Marceli Wein, were recently honored at the Festival of Computer Animation in Toronto. They were recognized as Fathers of Computer Animation Technology in Canada. Burtnyk, who began his career with NRC in 1950, started Canada's first substantive computer graphics research project in the 1960s. Wein, who joined this same project in 1966, had been exposed to the potential of computer imaging while studying at McGill. He teamed up with Burtnyk to pursue this promising field.

One of their main contributions was the Academy Award nominated film "Hunger/La Faim" (produced by the National Film Board of Canada) using their famous key-frame animation approach and system.

Related Glossary Terms: Burtnyk, Nestor

Term Source: Chapter 4 – JPL and National Research Council of Canada

Whirlwind

The Whirlwind computer was developed at the Massachusetts Institute of Technology. It is the first computer that operated in real time, used video displays for output, and the first that was not simply an electronic replacement of older mechanical systems. Its development led directly to the United States Air Force's Semi-Automatic Ground Environment (SAGE) system, and indirectly to almost all business computers and minicomputers in the 1960s.

Related Glossary Terms:

Term Source: Chapter 2 – Whirlwind and SAGE

Whitney, John Sr.

John Whitney, Sr. (April 8, 1917 – September 22, 1995) was an American animator, composer and inventor, widely considered to be one of the fathers of computer animation.

Related Glossary Terms:

Term Source: Chapter 2 – Programming and Artistry

Whitted, Turner

Turner Whitted is senior researcher and area manager at Microsoft Research. Whitted is an Association for Computing Machinery fellow and a member of the National Academy of Engineering. Whitted has served as a distinguished lecturer in the Rice University Department of Electrical and Computer Engineering. He is on the editorial boards of IEEE Computer Graphics and Applications and Association for Computing Machinery Transactions on Graphics. Whitted is credited with being the “father” of ray tracing, as exemplified with his famous short movie The Compleat Angler.

Related Glossary Terms:

Term Source: Chapter 5 – Cal Tech and North Carolina State

WIMP

In human–computer interaction, WIMP stands for “windows, icons, menus, pointer”, denoting a style of interaction using these elements of the user interface. It was coined by Merzouga Wilberts in 1980. Other expansions are sometimes used, substituting “mouse” and “mice” or “pull-down menu” and “pointing”, for menu and pointing, respectively

Related Glossary Terms: GUI (Graphical User Interface)

Term Source: Chapter 16 – Apple Computer

Wireframe

A wire frame model is a visual presentation of a three dimensional or physical object used in 3D computer graphics. It is created by specifying each edge of the physical object where two mathematically continuous smooth surfaces meet, or by connecting an object’s constituent vertices using straight lines or curves. The object is projected onto the computer screen by drawing lines at the location of each edge.The term wireframe comes from designers using metal wire to represent the 3 dimensional shape of solid objects.3D wireframe allows to construct and manipulate solids and solid surfaces.3D solid modeling technique efficiently draws high quality representation of solids than the conventional line drawing.

Related Glossary Terms:

Term Source: Chapter 15 – Graphics Accelerators

Witkin, Andrew

Andrew P. Witkin was an American computer scientist who made major contributions in computer vision and computer graphics. Witkin worked briefly at SRI International on computer vision, then moved to Schlumberger's Fairchild Laboratory for Artificial Intelligence Research, later Schlumberger Palo Alto Research, where he led research in computer vision and graphics; here he invented scale-space filtering, scale-space segmentation and Active Contour Models. From 1988 to 1998 he was a professor of computer science, robotics, and art at Carnegie-Mellon University, after which he joined Pixar in Emeryville, California. At CMU and Pixar, with his colleagues he developed the methods and simulators used to model and render natural-looking cloth, hair, water, and other complex aspects of modern computer animation. Witkin received the ACM SIGGRAPH Computer Graphics Achievement Award in 2001 "for his pioneering work in bringing a physics based approach to computer graphics." As senior scientist at Pixar Animation Studios, Witkin received a technical academy award in 2006 for "pioneering work in physically-based computer-generated techniques used to simulate realistic cloth in motion pictures.

Related Glossary Terms:

Term Source: Chapter 19 – Physical-based Modeling

Wozniak, Steve

Steve Wozniak (the Woz) is an American computer engineer and programmer who founded Apple Computer (now Apple Inc.) with Steve Jobs and Ronald Wayne. Wozniak is the inventor of the Apple I computer and its successor, the Apple II computer, which contributed significantly to the microcomputer revolution.

Related Glossary Terms:

Term Source: Chapter 16 – Apple Computer

WYSIWYG

an acronym for What You See Is What You Get. The term is used in computing to describe a system in which content (text and graphics) displayed onscreen during editing appears in a form closely corresponding to its appearance when printed or displayed as a finished product, which might be a printed document, web page, or slide presentation.

Related Glossary Terms:

Term Source: Chapter 16 – Xerox PARC

X/Y/Z

Zajac, Edward

Zajac is recognized internationally as the first person in history to create computer animation, at first as a visual means to share with his colleagues the positions of satellites as they orbit Earth. Appearing antiquated and simple in today's world, his early computer- animated films produced at Bell Labs won much acclaim at the time, and awards in the U.S. and oversees, and are considered classics today.

Related Glossary Terms:

Term Source: Chapter 4 – Bell Labs and Lawrence Livermore

Afterword



The *Road to Point Reyes* was developed by Lucasfilm Computer Graphics Project personnel (Alvy Ray Smith, Rob Cook, Loren Carpenter, Bill Reeves, Tom Porter and Davis Salesin) in 1983, and was featured as the title page image for the SIGGRAPH 83 conference proceedings. It was exhibited at the Computer Museum in Boston in 1984-1985. The goal at Lucasfilm was to create an image of the complexity and resolution to show that CG technology could be used effectively in the movie-making process. The image (4096×4096 at 24 bits per pixel)

has been called “a movie in a frame”, and showed the application of significant advances in the CG technology that were being perfected at Lucasfilm, including advanced 3D modeling, fractals, particle systems, “graftals”, compositing, texture mapping, advanced lighting and atmospheric effects, water and water effects, and graphics hardware and systems.

The image is a tribute to the researchers at Lucasfilm that subscribed to the philosophy that permeated the computer graphics discipline, that **advances in technology should be shared with peers in the interest of achieving the long term goals of creating better synthetic imagery**.